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Page numbers are given in the table below to indicate portions of the *Materials Manual* that are to be removed and inserted to accomplish this revision.

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TECHNICAL MANUAL

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Cement

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T	22	WSDOT	✓	✓	FOP for AASHTO for Compressive Strength of Cylindrical Concrete Specimens
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T	106	WSDOT	✓	✓	FOP for AASHTO for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or (50-mm) Cube Specimens)
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T	119	WSDOT	✓	✓	FOP for AASHTO for Standard Test Method for Slump of Hydraulic-Cement Concrete
T	121	AASHTO	✓	✓	Mass per Cubic Meter (Cubic Foot), Yield, and Air Content (Gravimetric) of Concrete (Checklist Only)
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Procedure	Number	Owner	Field Use	In Manual	Test Method
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T	198	AASHTO			Splitting Tensile Strength of Cylindrical Concrete Specimens
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T	231	WSDOT	✓	✓	FOP for AASHTO for Capping Cylindrical Concrete Specimens
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D	1429	ASTM			Standard Test Methods for Specific Gravity of Water and Brine
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Electrical & Traffic

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T	429	WSDOT	✓	✓	Retroreflectance of Newly Applied Pavement Marking Using Portable Hand-Operated Instruments
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Procedure	Number	Owner	Field Use	In Manual	Test Method
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D	2488	ASTM			Visual Manual Soil Identification
D	4354	ASTM		✓	Standard Practice for Sampling of Geosynthetics for Testing
D	7012	ASTM			Standard Test Method for Compressive Strength and Elastic Moduli of Intact Rock Core Specimens under Varying States of Stress and Temperatures
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T	244	AASHTO			Mechanical Testing of Steel Products
A	370	ASTM			Mechanical Testing
F	606	ASTM			Mechanical Properties: Steel Fasteners
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T	915	WSDOT		✓	Practice for Conditioning of Geotextiles for Testing
T	923	WSDOT		✓	Thickness Measurement of Geotextiles
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Procedure	Number	Owner	Field Use	In Manual	Test Method
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D	4533	ASTM			Tear Strength (Geotextiles)
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	4061	FTMS			Method for Determination of Drying Time (Oil-Based Paints)
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Procedure	Number	Owner	Field Use	In Manual	Test Method
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T	272	WSDOT	✓	✓	FOP for AASHTO for Family of Curves — One Point Method
T	307	AASHTO		✓	Resilient Modulus of Subgrade Soils and Untreated Base/Subbase Materials
T	310	WSDOT	✓	✓	FOP for AASHTO for In-Place Density and Moisture Content of Soil and Soil-Aggregate by Nuclear Methods (Shallow Depth)
T	601	WSDOT		✓	Method of Test for Sieve Analysis of Soils-Coarse Sieving
T	606	WSDOT		✓	Method of Test for Compaction Control of Granular Materials
T	610	WSDOT		✓	Method of Test for the Capillary Rise of Soils
T	611	WSDOT		✓	Method of Test for Determination of the Resistance (R-Value) of Untreated Bases, Subbases, and Basement Soils by the Stabilometer
SOP	615	WSDOT	✓	✓	Determination of the % Compaction for Embankment & Untreated Surfacing Materials using the Nuclear Moisture-Density Gauge
T	807	WSDOT	✓	✓	Method of Operation of California Profilograph and Evaluation of Profiles
D	4694	ASTM			Test Method for Deflections With Falling-Weight Type Impulse Load Device
					Standard Practice
QC 1	WSDOT			✓	Standard Practice for Cement Producers That Certify Portland Cement
QC 2	WSDOT			✓	Standard Practice for Asphalt Suppliers That Certify Performance Graded Asphalts
QC 3	WSDOT			✓	Quality System Laboratory Review

Procedure	Number	Owner	Field Use	In Manual	Test Method
					Part 2 Master Content
QC	1	WSDOT		✓	Standard Practice for Cement Producers That Certify Portland Cement
QC	2	WSDOT		✓	Standard Practice for Asphalt Suppliers That Certify Performance Graded Asphalts
QC	3	WSDOT		✓	Quality System Laboratory Review
T	2	WSDOT	✓	✓	FOP for AASHTO for Sampling of Aggregate
TM	2	WAQTC	✓	✓	FOP for WAQTC for Sampling Freshly Mixed Concrete
D	4	ASTM			Standard Test Method for Bitumen Content
TM	8	WAQTC	✓	✓	FOP for WAQTC for In-Place Density of Bituminous Mixes Using the nuclear Moisture-Density Gauge
T	11	AASHTO			Materials Finer Than 0.075 mm (No. 200) Sieve in Mineral Aggregates by Washing
T	19	AASHTO	✓	✓	Unit Weight and Voids in Aggregates (Checklist Only)
T	21	AASHTO			Organic Impurities in Fine Aggregates for Concrete
T	22	AASHTO			Compressive Strength of Cylindrical Concrete Specimens
T	22	WSDOT	✓	✓	FOP for AASHTO for Compressive Strength of Cylindrical Concrete Specimens
T	23	AASHTO			Making and Curing Concrete test Specimens in the Field
T	23	WSDOT	✓	✓	FOP for AASHTO for Making and Curing Concrete test Specimens in the Field
T	27	AASHTO			Sieve Analysis of Fine and Coarse Aggregates
T	27/11	WSDOT	✓	✓	FOP for WAQTC/AASHTO for Sieve Analysis of Fine and Coarse Aggregates
R	28	AASHTO			Practice of Accelerated Aging of Asphalt Binder Using a Pressurized Aging Vessel
R	29	AASHTO			Practice for Grading or Verifying the Performance Grade of an Asphalt Binder
R	30	AASHTO			Practice for Short and Long Term Aging of Hot Mix Asphalt (HMA)
T	30	AASHTO			Mechanical Analysis of Extracted Aggregate
T	37	AASHTO			Sieve Analysis of Mineral Filler
R	39	AASHTO			Making and curing Concrete Test Specimens in the Laboratory
T	40	AASHTO			Method of Test for Determination of the Density of Portland Cement Concrete Pavement Cores
T	40	WSDOT	✓	✓	FOP for WAQTC/AASHTO for Sampling Bituminous Materials
T	44	AASHTO			Solubility of Bituminous Materials
T	48	AASHTO			Flash and Fire Points by Cleveland Cup
T	49	AASHTO			Penetration of Bituminous Materials

Procedure	Number	Owner	Field Use	In Manual	Test Method
T	50	AASHTO			Float Test for Bituminous Materials
T	51	AASHTO			Ductility of Bituminous Materials
T	53	AASHTO			Softening point of Bituminous (Ring and Ball Apparatus)
T	55	AASHTO			Water in Petroleum Products and Bituminous Materials by Distillation
T	59	AASHTO			Testing Emulsified Asphalts
T	65	AASHTO			Mass (Weight) of Coating on Iron and Steel Articles with Zinc or Zinc-Alloy Coatings
T	71	AASHTO			Effect of Organic Impurities in Fine Aggregate on Strength of Mortar
T	72	AASHTO			Saybolt Viscosity
T	78	AASHTO			Distillation of Cut Back Asphaltic (Bituminous) Products
IP	78-16	FHWA			Signal Controller Evaluation
T	79	AASHTO			Flash Point with Tag Open-Cup Apparatus for Use with Materials Having a Flash Less Than 93.3°C (200°F) 207
T	84	AASHTO			Specific Gravity and Absorption of Fine Aggregates
T	85	AASHTO			Specific Gravity and Absorption of Coarse Aggregates
T	87	AASHTO			Dry Preparation of Disturbed Soil and Soil Aggregate Samples for Test
T	88	AASHTO			Particle Size Analysis of Soils
T	89	AASHTO			Determining the Liquid Limit of Soils
T	90	AASHTO		✓	Determining the Plastic Limit and Plasticity Index of Soils (Checklist Only)
T	96	AASHTO			Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine
T	99	AASHTO			The Moisture-Density Relations of Soils Using a 2.5 kg (5.5 lb) Rammer and a 305 mm (12 in) Drop
T	99	WSDOT	✓	✓	FOP for AASHTO for Moisture-Density Relations of Soils Using a 5.5-lb (2.5-kg) Rammer and a 12-in. (305-mm) Drop
T	100	AASHTO			Specific Gravity of Soils
T	105	AASHTO			Chemical Analysis of Hydraulic Cement
T	106	AASHTO			Compressive Strength of Mortars (Using 0-mm or 2-in.) Cube Specimens
T	106	WSDOT	✓	✓	FOP for AASHTO for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or (50-mm) Cube Specimens)
T	107	AASHTO			Autoclave Expansion of Portland Cement
T	111	AASHTO			Inorganic Matter or Ash in Bituminous Materials
T	112	AASHTO		✓	Clay Lumps and Friable Particles in Aggregates

Procedure	Number	Owner	Field Use	In Manual	Test Method
D	113	ASTM			Standard Test Method for Ductility of Bituminous Materials
T	113	WSDOT		✓	Method of Test for Determination of Degradation Value
T	119	AASHTO			Slump of Hydraulic Cement Concrete
T	119	WSDOT	✓	✓	FOP for AASHTO for Standard Test Method for Slump of Hydraulic-Cement Concrete
T	121	AASHTO			Mass per Cubic Meter (Cubic Foot), Yield, and Air Content (Gravimetric) of Concrete
T	123	WSDOT	✓	✓	Method of Test for Bark Mulch
T	124	WSDOT			Method of Testing Top Soils
T	125	WSDOT		✓	Determination of Fiber Length Percentages in Wood Strand Mulch
T	126	WSDOT		✓	Determination of Fiber Length Percentages in Hydraulically-Applied Erosion Control Products
SOP	128	WSDOT	✓	✓	Sampling For Aggregate Source Approval
T	129	AASHTO			Normal Consistency of Hydraulic Cement
T	131	AASHTO			Time of Setting of Hydraulic Cement by Vicat Needle
T	133	AASHTO			Density of Hydraulic Cement
T	137	AASHTO			Air Content of Hydraulic Cement Mortar
C	140	ASTM			Absorption and Compressive Strength of Concrete Masonry Units
T	141	AASHTO			Sampling Freshly Mixed Concrete
A	143	ASTM			Standard Practice for Safeguarding Against Embrittlement of Hot-Dip Galvanized Structural Steel Products and Procedure for Detecting Embrittlement
T	152	AASHTO			Air Content of Freshly Mixed Concrete by the Pressure Method
T	152	WSDOT	✓	✓	FOP for WAQTC/AASHTO for Air Content of Freshly Mixed Concrete by the Pressure Method
T	153	AASHTO			Fineness of Portland Cement by Air Permeability Apparatus
T	154	AASHTO			Time of Setting of Hydraulic Cement by Gillmore Needle
T	162	AASHTO			Mechanical Mixing of Hydraulic Cement Pastes and Mortars of Plastic Consistency
T	166	AASHTO			Bulk Specific Gravity of Compacted Asphalt Mixtures Using Saturated Surface-Dry Specimens
T	166	WSDOT	✓	✓	FOP for AASHTO for Bulk Specific Gravity of Compacted Bituminous Mixtures Using Saturated Surface-Dry Specimens
T	168	AASHTO			Sampling Bituminous Paving Mixtures
T	168	WSDOT	✓	✓	FOP for WAQTC/AASHTO for Sampling Hot Mix Asphalt
T	176	AASHTO			Plastic Fines in Graded Aggregates and Soils by Use of the Sand Equivalent Test

Procedure	Number	Owner	Field Use	In Manual	Test Method
T	176	WSDOT	✓	✓	FOP for AASHTO for Plastic Fines in Graded Aggregates and Soils by Use of the Sand Equivalent Test
T	177	AASHTO			Flexural Strength of Concrete (Using Simple Beam With Center-Point Loading)
T	180	WSDOT	✓	✓	FOP for AASHTO for Moisture-Density Relations of Soils Using a 10-lb (4.54-kg) Rammer and an 18-in. (457-mm) Drop
D	185	ASTM			Standard Test Methods for Coarse Particles in Pigments, Pastes, and Paints
T	196	AASHTO		✓	Air Content of Concrete (Volumetric Method) (Checklist Only)
T	197	AASHTO			Time of Setting of Concrete Mixtures by Penetration Resistance
T	198	AASHTO			Splitting Tensile Strength of Cylindrical Concrete Specimens
T	200	AASHTO			pH of Aqueous Solutions with the Glass Electrode
T	201	AASHTO			Kinematic Viscosity of Asphalts
T	202	AASHTO			Viscosity of Asphalts by Vacuum Capillary Viscometer
T	208	AASHTO			Unconfined Compressive Strength of Cohesive Soils
T	209	AASHTO			Theoretical Maximum Specific Gravity and Density of Bituminous Paving Mixtures
T	209	WSDOT	✓	✓	FOP for AASHTO for Method of Test for Maximum Specific Gravity of Hot Mix Asphalt — “Rice Density”
T	215	AASHTO			Permeability of Granular Soils (Constant Head)
T	216	AASHTO			One-Dimensional Consolidation Properties of Soils
D	217	ASTM			Standard Test Methods for Cone Penetration of Lubricating Grease
T	217	WSDOT	✓	✓	FOP for AASHTO for Determination of Moisture in Soils by means of a Calcium Carbide Gas Pressure Moisture Tester
T	224	AASHTO			Standard Method of Test for Correction for Coarse Particles in the Soil Compaction Test
T	228	AASHTO			Specific Gravity of Semi-Solid Bituminous Materials
T	229	AASHTO			Density of Solid Pitch and Asphalt (Displacement Method)
T	231	AASHTO			Capping Cylindrical Concrete Specimens
T	231	WSDOT	✓	✓	FOP for AASHTO for Capping Cylindrical Concrete Specimens
T	236	AASHTO			Direct Shear test of Soils Under Consolidated Drained Conditions
T	240	AASHTO			Effect of Heat and Air on a Moving Film of Asphalt (Rolling Thin-Film Oven Test)
T	242	AASHTO			Frictional Properties of Paved Surfaces Using a Full-Size Tire

Procedure	Number	Owner	Field Use	In Manual	Test Method
T	244	AASHTO			Mechanical Testing of Steel Products
T	248	AASHTO			Reducing Field Samples of Aggregates to Testing Size
T	248	WSDOT	✓	✓	FOP for AASHTO for Reducing Samples of Aggregate to Testing Size
T	255	AASHTO			Total Moisture Content of Aggregate by Drying
T	255	WSDOT	✓	✓	FOP for AASHTO for Total Moisture Content of Aggregate by Drying
T	257	AASHTO			Instrumental Photometeric Measurements of Retroreflectivie Material and Retroreflective
T	260	AASHTO			Sampling and Testing for Chloride Ion in Concrete and Concrete Raw Materials
T	265	AASHTO		✓	Laboratory Determination of Moisture Content of Soils
T	267	AASHTO			Determination of Organic Content in Soils by Loss on Ignition
T	269	AASHTO			Percent Air Void in Compacted Dense and Open Bituminous Paving Mixtures
T	272	AASHTO			Family of Curves — One Point Method
T	272	WSDOT	✓	✓	FOP for AASHTO for Family of Curves — One Point Method
T	275	AASHTO			Bulk Specific Gravity of Compacted Bituminous Mixtures Using Paraffin-Coated Specimens
T	277	AASHTO			Electrical Indication of Concrete's Ability to Resist Chloride Ion Pentetration
T	288	AASHTO		✓	Determining Minimum Laboratory Soil Resistivity(checklist only)
T	289	AASHTO			Determining pH of Soil for Use in Corrosion
T	295	AASHTO			Specific Gravity or API Gravity of Liquid Asphalt by Hydrometer
T	296	AASHTO			Unconsolidated, Undrained Compressive Strength of Cohesive Soils in Triaxial Compression
T	297	AASHTO			Consolidated, Undrained Triaxial Compressive Test on Cohesive Soils Shear
T	303	AASHTO			Accelerated Detection of Potentially Deleterious Expansion of Mortar Bars Due to Alkali-Silica Reaction
T	304	WSDOT	✓	✓	FOP for AASHTO for Uncompacted Void Content of Fine Aggregate
T	307	AASHTO		✓	Resilient Modulus of Subgrade Soils and Untreated Base/Subbase Materials
T	308	AASHTO			Determining the Asphalt Binder Content of Hot Mix Asphalt (HMA) by the Ignition Method
T	308	WSDOT	✓	✓	FOP for AASHTO for Determining the Asphalt Binder Content of Hot Mix Asphalt (HMA) by the Ignition Method

Procedure	Number	Owner	Field Use	In Manual	Test Method
T	418	WSDOT		✓	Method of test for Corrosion of Deicing Materials
T	419	WSDOT		✓	Test Method for Cold Temperature Impact Resistance of the Plastic Coating on Reinforcing Bar Chair Feet
T	420	WSDOT	✓	✓	Test Method for Determining the Maturity of Compost (Solvita Test)
T	421	WSDOT		✓	Test Method for Traffic Controller Inspection and Test Procedure
T	422	WSDOT		✓	Test Method for Traffic Controller Transient Voltage Test (Spike Test) Procedure
T	423	WSDOT		✓	Traffic Controller Conflict Monitor Testing
T	424	WSDOT		✓	Traffic Controller Power Interruption Test Procedure
T	425	WSDOT		✓	Traffic Controller NEMA and 170 Type Environmental Chamber Test
T	426	WSDOT		✓	Pull-Off Test for Hot Melt Traffic Button Adhesive
T	427	WSDOT		✓	Loop Amplifier Testing Procedure
T	428	WSDOT		✓	Test Method for Traffic Controller Compliance Inspection and Test Procedure
T	429	WSDOT	✓	✓	Retroreflectance of Newly Applied Pavement Marking Using Portable Hand-Operated Instruments
SOP	429	WSDOT		✓	Methods for Determining the Acceptance of Traffic Signal Controller Assembly
T	430	WSDOT		✓	Method of Testing for the Presence of Adhesion Coating in Glass Beads
C	457	ASTM			Standard Test Method for Microscopical Determination of Parameters of the Air-Void System in Hardened Concrete
D	470	ASTM			Test Method for Crossedlinked Insulation and Jackets for Wire and Cable
C	495	ASTM			Compressive Strength of Lightweight Insulated Concrete
D	562	ASTM			Method for Determination of Consistency of Paints Using the Stormer Viscometer
D	562	ASTM			Using the Stormer Viscometer for Curing Compounds
T	601	WSDOT		✓	Method of Test for Sieve Analysis of Soils-Coarse Sieving
T	606	WSDOT		✓	Method of Test for Compaction Control of Granular Materials
F	606	ASTM			Mechanical Properties: Steel Fasteners
T	610	WSDOT		✓	Method of Test for the Capillary Rise of Soils
T	611	WSDOT		✓	Method of Test for Determination of the Resistance (RValue) of Untreated Bases, Subbases, and Basement Soils by the Stabilometer
SOP	615	WSDOT	✓	✓	Determination of the % Compaction for Embankment & Untreated Surfacing Materials using the Nuclear Moisture-Density Gauge

Procedure	Number	Owner	Field Use	In Manual	Test Method
DMCT	700	ATSI			Manual on Signal Controller Evaluation
T	702	WSDOT		✓	Method for Preparation of Test Specimens of Hot Mix Asphalt by Means of California Kneading Compactor
T	703	WSDOT		✓	Method of Test for Resistance to Deformation of Hot Mix Asphalt by Means of HVEEM Stabilometer
T	706	WSDOT		✓	Method of Static Immersion Asphalt in Water Preferential Stripping Test
T	712	WSDOT	✓	✓	Standard Method of Reducing Hot Mix Asphalt
T	716	WSDOT	✓	✓	Method of Random Sampling for Location of Testing and Sampling Sites
T	718	WSDOT		✓	Method of Test for Determining Stripping of Hot Mix Asphalt
T	720	WSDOT		✓	Method of Test for Thickness Measurement of Hot Mix Asphalt Cores
T	724	WSDOT	✓	✓	Method for Preparation of Aggregate for HMA Job Mix Design
T	726	WSDOT	✓	✓	Mixing Procedure for Hot Mix Asphalt
SOP	728	WSDOT	✓	✓	Standard Operating Procedure for Determining the Ignition Furnace Calibration Factor (IFCF) for Hot Mix Asphalt (HMA)
SOP	729	WSDOT	✓	✓	In-Place Density of Bituminous Mixes Using the Nuclear Moisture-Density Gauge FOP for WAQTC TM 8
SOP	730	WSDOT	✓	✓	Standard Operating Procedure for Correlation of Nuclear Gauge Determined Density with Asphalt Concrete Pavement Cores
SOP	731	WSDOT	✓	✓	Method for Determining Volumetric Properties of Asphalt Concrete Pavement Class Superpave
SOP	732	WSDOT	✓	✓	Standard Operating Procedure for Superpave Volumetric Design for Hot-Mix Asphalt (HMA)
SOP	733	WSDOT	✓	✓	Standard Operating Procedure for Determination of PavementDensity Differentials Using the Nuclear Density Gauge
SOP	734	WSDOT	✓	✓	Standard Operating Procedure for SAMPLING HOT MIX ASPHALT AFTER COMPACTION (OBTAINING CORES)
SOP	735	WSDOT	✓	✓	Standard Operating Procedure for Longitudinal Joint Density
T	802	WSDOT	✓	✓	Method of Test for Flexural Strength of Concrete (Using Simple Beam With Center-Point Loading)
C	805	ASTM			Test Method for Rebound Number of Hardened Concrete
C	805	WSDOT	✓	✓	Rebound Hammer Determination of Compressive Strength of Hardened Concrete
T	807	WSDOT	✓	✓	Method of Operation of California Profilograph and Evaluation of Profiles

Procedure	Number	Owner	Field Use	In Manual	Test Method
T	808	WSDOT	✓	✓	Method for Making Flexural Test Beams
T	810	WSDOT	✓	✓	Method of Test for Determination of the Density of Portland Cement Concrete Pavement Cores
T	812	WSDOT	✓	✓	Method of Test for Measuring Lenght of Drilled Concrete Cores
T	813	WSDOT	✓	✓	Field Method of Fabrication of 50-mm (2-in.) Cube Specimens for Compressive Strength Testing of Grouts and Mortars
T	814	WSDOT		✓	Method of Test for Water Retention Efficiency of Liquid Membrane-Forming Compounds and Impermeable Sheet Materials for Curing Concrete
T	816	WSDOT		✓	Method of Test for Parting Compound
T	818	WSDOT		✓	Air Content of Freshly Mixed Self-Compacting Concrete by the Pressure Method
T	819	WSDOT		✓	Making and Curing Self-Compacting Concrete Test Specimens in the Field
C	882	ASTM		✓	Standard Test Method for Bond Strength of Epoxy-Resin Systems used with Concrete by Slant Shear
T	914	WSDOT	✓	✓	Practice for Sampling of Geotextiles for Testing
T	915	WSDOT		✓	Practice for Conditioning of Geotextiles for Testing
T	923	WSDOT		✓	Thickness Measurement of Geotextiles
T	925	WSDOT		✓	Standard Practice for Determination of Long-Term Strength for Geosynthetic Reinforcement
T	926	WSDOT		✓	Geogrid Brittleness Test
C	939	ASTM			Standard Test Method for Flow of Grout for Preplaced-Aggregate Concrete (Flow Cone Method)
C	939	WSDOT	✓	✓	FOP for ASTM for Flow of Grout for Preplaced-Aggregate Concrete (Flow Cone Method)
D	1208	ASTM			Method for Determination of Loss on Ignition
D	1210	ASTM			Standard Test Method for Fineness of Dispersion of Pigment-Vehicle Systems by Hegman-Type Gage
C	1218	ASTM			Standard Test Method for Water-Soluble Chloride in Mortar and Concrete
D	1298	ASTM			Standard Practice for Density, Relative Density (Specific Gravity), or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method
D	1429	ASTM			Standard Test Methods for Specific Gravity of Water and Brine
D	1475	ASTM			Test Method for Consistency of Paints Test Method for Density of Paint, Varnish, Lacquer, and Related Products

Procedure	Number	Owner	Field Use	In Manual	Test Method
C	1611	WSDOT	✓	✓	FOP for ASTM C 1611/C 1611M Standard Test Method for Slump Flow of Self-Consolidating Concrete
C	1621	WSDOT	✓	✓	WSDOT FOP for ASTM C 1621/C 1621M Standard Test Method for Passing Ability of Self-Consolidating Concrete by J-Ring
D	1683	ASTM			Sewen Seams
PCMZ	2000	TS			Manual on Signal Controller Evaluation
D	2007	ASTM			Standard Test Method for Characteristic Groups in Rubber Extender and Processing Oils and Other Petroleum-Derived Oils by the Clay-Gel Absorption Chromatographic Method
D	2196	ASTM			Standard Test Methods for Rheological Properties of Non-Newtonian Materials by Rotational (Brookfield) Viscometer
D	2369	ASTM			Method for Determination of Volatile and Nonvolatile Content (Ordinary Laboratory Oven)
D	2371	ASTM			Standard Test Method for Pigment Content of Solvent-Reducible Paints (Centrifuge)
D	2487	ASTM			Identification and Classification of Soils for Engineering Purposes
D	2488	ASTM			Visual Manual Soil Identification
D	2621	ASTM			Standard Test Method for Infrared Identification of Vehicle Solids From Solvent-Reducible Paints
D	2628/ M 220	ASTM		✓	Standard Specification for Preformed Polychloroprene Elastomeric Joint Seals for Concrete Pavements (Checklist Only)
D	2633	ASTM			Thermoplastic Insulation
D	2697	ASTM			Standard Test Method for Volume Nonvolatile Matter in Clear or Pigmented Coatings
	3011	FTMS			Method for Determination of Condition in Container
D	3723	ASTM			Standard Test Method for Pigment Content of Water Emulsion Paints by Temperature Ashing
D	3786	ASTM			Burst Test
	4053	FTMS			Method for Determination of Nonvolatile Vehicle Content
	4061	FTMS			Method for Determination of Drying Time (Oil-Based Paints)
	4122	FTMS			Method for Determination of Hiding Power (Contrast Ratio)
D	4354	ASTM		✓	Standard Practice for Sampling of Geosynthetics for Testing
D	4355	ASTM			Standard Test Method for Deterioration of Geotextiles from Exposure to Ultraviolet Light and Water (Xenon-Arc Type Apparatus)

Washington State
Department of Transportation

WSDOT Standard Practice QC 3

Quality System Laboratory Review

1. SCOPE

    This standard specifies requirements and procedures for the review of WSDOT Regional Materials Laboratory and for Private Laboratories by the Quality Systems Laboratory Review Team. The on-site laboratory review shall include the following elements:

    - Review of the testing facility
    - Review of the equipment calibration/verification records
    - Review of the testing technician's training records
    - Physical inspection of the equipment used to perform tests
    - Observation of technician performing the test procedure
    - Review of Test Reports and Calculations

2. REFERENCED DOCUMENTS

    2.1 AASHTO Standards:

    R-18 Establishing and Implementing a Quality System for Construction Materials Testing Laboratories

    PP 57 Establishing Requirements for and Performing Equipment Calibrations, Standardizations, and Checks

    2.2 WSDOT Standards:

    WSDOT *Materials Manual*

    WSDOT *Construction Manual*

    WSDOT *Standard Specification*

3. TERMINOLOGY

    3.1 AASHTO — American Association of State Highway and Transportation Officials

    3.2 ASTM — American Society for Testing and Materials

    3.3 Calibration—a process that establishes the relationship (traceability) between the results of a measurement instrument, measurement system, or material measure and the corresponding values assigned to a reference standard (Note 1).

    Note 1 — This definition for calibration and the following definitions for check, standardization, traceability, uncertainty, and verification of calibration are based on the definitions in PP 57.

3.4 Check — a specific type of inspection and/or measurement performed on equipment and materials to indicate compliance or otherwise with stated criteria.

3.5 Standardization — a process that determines (1) the correction to be applied to the result of a measuring instrument, measuring system, material measure or reference material when its values are compared to the values realized by standards, or (2) the adjustment to be applied to a piece of equipment when its performance is compared with that of an accepted standard or process.

3.6 WSDOT — Washington State Department of Transportation

4. SIGNIFICANCE AND USE

4.1 This standard specifies procedures for reviewing laboratories for the purpose of determining the capability of the facility and its personnel to perform the necessary acceptance testing for WSDOT.

5. LABORATORY REQUIREMENTS

5.1 Facility and Equipment

5.1.1 Laboratory facilities shall adequately house and allow proper operation of all required equipment in accordance with the applicable test procedures.

5.1.2 The temperature and humidity of the laboratory shall meet the requirements of all test procedures performed in the laboratory.

5.1.3 The testing areas shall be clean and free of clutter.

5.1.4 The laboratory shall use testing equipment that meets the requirements of each test procedure.

5.1.5 Testing equipment for private laboratories and the State Materials Laboratory shall be calibrated/standardized/checked in accordance with the test procedure, appropriate sections of AASHTO R-18 and AASHTO PP 57. WSDOT Region and Field laboratories testing equipment shall be calibrated/standardized/checked in accordance with the test procedure and Section 9-5.5A(4) of the WSDOT Construction Manual.

5.1.6 Documentation of equipment calibration/standardization/check shall be maintained and available onsite during laboratory review.

5.1.7 Safety equipment will be available and maintained in proper working order.

5.2 Tester Training and Records

5.2.1 The laboratory shall use personnel qualified in accordance with the appropriate sections of AASHTO R-18. WSDOT Region and Field laboratory personnel shall be qualified in accordance with 9-5.5 of the WSDOT Construction Manual.

5.2.2 The laboratory shall maintain records of training for each tester.

5.2.3 A tester’s competency for performing a test procedure shall be evaluated using a checklist relating to the test procedure. The checklist shall be filed in the tester’s training record.

Note: Private laboratories may use test procedure checklists from the WSDOT Materials Manual, or may develop their own checklists similar to those found in the Materials Manual.

5.2.4 Testers for private laboratories shall be reviewed for qualification at the frequency stated in the laboratory's Quality Systems Manual.

5.3 Manuals and Records

5.3.1 Private laboratories shall have an up-to-date Laboratory Quality Systems Manual (LQSM) meeting the requirements of AASHTO R 18 and approved by the State Materials Engineer.

5.3.2 All private laboratories shall have an up-to-date copy of the LQSM on site and available to all testers.

5.3.3 Each tester must have access to the most current copy of the AASHTO, ASTM and the WSDOT Materials Manual. WSDOT testers must have access to the most current copy of the WSDOT Construction Manual.

5.3.4 If an earlier version of the WSDOT Materials or Construction Manual is required by contract, the laboratory shall maintain an unaltered version of the required manual.

5.3.5 A file of MSDS sheets must be maintained in the laboratory and must be available to all testers.

5.3.6 Test records are required to contain sufficient information to permit verification of any test report (original observations, calculations, derived data and identification of personnel involved in the sampling and testing).

5.3.7 Amendments to reports must be made in the manner stated in the LQSM.

5.3.8 The laboratory shall define the process used to insure testers are performing the correct testing procedure according to the clients' contractual requirements (i.e. AASHTO, ASTM or WSDOT test procedure as required by the contract).

5.3.9 Test reports are required to contain the following information:

- Name and address of the testing laboratory
- Name and address of the client or identification of the project
- Date of receipt of the test sample
- Date of test performance
- Identification of the standard test method used and notation of all know deviations from the test method
- Test results and specification of the material
- Name of tester performing the test
- Date report was issued
- Name of person accepting technical responsibility for test report

6. SAMPLING

6.1 Test samples required for observation of test procedures shall be obtained by:

WSDOT FOP for AASHTO T 2 for Soils and Aggregate

WSDOT FOP for AASHTO T 168 for Hot Mix Asphalt

WSDOT FOP for WAQTC TM 2 for Concrete

7. SAMPLE PREPARATION REQUIREMENTS

7.1 Prior to the performance portion of the laboratory review, for the testing being performed, samples are required to be prepared as shown in Table 1.

8. LABORATORY REVIEW TEAM REQUIREMENTS

8.1 The Laboratory review team will review the facility, equipment, records and testers compliance with the established requirements. .

8.2 The evaluation report will be prepared and sent to the laboratory within 30 days of the completion of the review.

8.3 Any items that did not meet the requirements of Section 5 will be written up as "Issues."

8.3.1 Issues resolved during the review shall be noted as "Resolved No Response necessary.

8.3.2 Issues that were not able to be resolved during the review will be noted as "Response Required."

8.4 The evaluation report may; approve the laboratory, give conditional approval provided the deficiencies are corrected or disapprove the laboratory until deficiencies are corrected and a re-inspection has been performed.

9. RESPONSE TO REPORT

9.1 Once the evaluation report has been received the laboratory will have 90 days to respond in writing to all "Issues" which labeled "Response Required."

9.2 The response must be a detailed explanation stating how the laboratory has resolved the issue and what measures they have taken to prevent this issue from reoccurring in the future.

Test Procedure	Test	Required Preparation
Aggregate Tests		
FOP for AASHTO T 335	Fracture	Material washed, graded and ready for counting fracture
FOP for AASHTO T 27/11	Sieve Analysis of Fine and Coarse Aggregates	Split or quarter proper amount of the original sample and dry to constant weight. Have a duplicate sample that has been washed and dried, ready for sieving. Retain all weights in order to do calculations.
FOP for AASHTO T 176	Sand Equivalent Test	Split or quarter enough of the original sample to yield approx. 1000 g of #4 minus. Do not sieve over the #4. Have 2 tins that have been properly prepared ready for introduction into the SE tube.
FOP for AASHTO T 248	Reducing Sample	30 lbs dry material
Concrete Tests		
FOP for AASHTO T 106	Compressive strength	3 mortar cubes
FOP for AASHTO T 22	Compressive strength	2 cylinders
FOP for AASHTO T 231	Capping cylinder	Capping compound ready to perform capping. Have 2 cylinders available for capping (can be the cylinders for T 22)
Soils Tests		
WSDOT T 417	Resistivity & pH	1500 g of #8 minus soil
AASHTO T 84	Specific gravity & absorption Fine Agg.	Prepare sample to step 6.1.2 of the procedure
AASHTO T 85	Specific gravity & absorption Coarse Agg.	Prepare sample to step 8.2 of the procedure
AASHTO T 87	Dry Preparation of Disturbed Soil and Soil Aggregate Samples for Test	500 g of soil aggregate air dried
AASHTO T 88	Particle Size Analysis	No preparation
AASHTO T 100	Specific gravity soils	No preparation
AASHTO T 255	Moisture Content	No preparation
AASHTO T 265	Moisture Content	No preparation
FOP for AASHTO T 99/T 180	Proctor	Enough #4 or ¾” material prepared for a five point proctor determination. Prepare five representative samples with approximately 2% moisture already added to each sample and starting at approximately 4% below optimum moisture of the material. Store in sealed containers.
WSDOT T 606	Maximum Density Curve	Split a sample of material into coarse and fine material. Prepare material to step 1.3e of Test No. 1. Also, prepare material to either 2.3a of Test 2, Procedure 1 or step 2.5b of Test 2, Procedure 2.
Hot Mix Asphalt Tests		
WSDOT T 712	Reducing Sample	Have a 25 lb box of HMA heated up and ready to reduce. Required to split material from sample for T 308, T 312, T 329, T 209
FOP for AASHTO T 166	Bulk Specific Gravity	A room temperature compacted sample must be provided for this test. A gyratory sample or a core sample will suffice
WSDOT SOP 724	Preparation of Aggs.	Representative aggregate from stockpiles used in JMF, dried to a constant weight
WSDOT SOP 726	Mixing Procedure HMA	Binder used in JMF mix design heated to mixing temperature as recommended by binder supplier (typically one quart container). Aggregate representative of JMF sample size based on class of HMA heated to mixing temperature as recommended by binder supplier

Sample Preparation Requirements
Table 1

Performance Exam Checklist

AASHTO T 19M/T 19
Bulk Density ("Unit Weight") and Voids in Aggregate (Rodding Procedure Only)

Participant Name ______________________ Exam Date ______________

Procedure Element	**Yes**	**No**
1. The tester has a copy of the current procedure on hand?	❒	❒
2. All equipment is functioning according to the test procedure, and if required, has the current calibration/verification tags present?	❒	❒
3. Sample is approximately 125 to 200% of quantity required to fill measure?	❒	❒
4. Sample is handled correctly to avoid segregation?	❒	❒
5. Sample is dried to a constant mass in accordance with WSDOT FOP for AASHTO T 255?	❒	❒
Rodding Procedure		
6. Mass of empty unit weight measure is determined and recorded (nearest 0.1 lb)?	❒	❒
7. Measure is filled in three equal layers?	❒	❒
8. Each layer is rodded throughout it's depth 25 times with a hemispherical end of rod but rodding does not penetrating into the next layer?	❒	❒
9. Rodding is evenly distributed over the surface of the sample?	❒	❒
10. Mass of unit weight measure plus contents is determined to the nearest 0.1 lb and recorded?	❒	❒
11. All calculations performed correctly?	❒	❒
12. Bulk density reported to the nearest 1 lb/ft^3?	❒	❒

First attempt: Pass ❒ Fail ❒ Second attempt: Pass ❒ Fail ❒

Signature of Examiner ______________________________

Comments:

WSDOT FOP for AASHTO T 23[1]

Making and Curing Concrete Test Specimens in the Field

1. SCOPE

1.1 This method covers procedures for making and curing cylinder specimens from representative samples of fresh concrete for a construction project.

1.2 The concrete used to make the molded specimens shall be sampled after all on-site adjustments have been made to the mixture proportions, including the addition of mix water and admixtures, except as modified in Section 5.1. This practice is not satisfactory for making specimens from concrete not having measurable slump or requiring other sizes or shapes of specimens.

1.3 The values stated in English units are to be regarded as the standard.

1.4 This standard does not purport to address the safety problems associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. (**Warning-** Fresh hydraulic cementitious mixtures are caustic and may cause chemical burns to exposed skin and tissue upon prolonged exposure.)

2. REFERENCED DOCUMENTS

2.1 AASHTO Standards

T 23 Making and Curing Concrete Test Specimens in the Field

M 201 Moist Cabinets, Moist Rooms, and Water Storage Tanks Used in the Testing of Hydraulic Cements and Concretes

M 205 Molds for Forming Concrete Test Cylinders Vertically

R 39 Making and Curing Concrete Test Specimens in the Laboratory

T 231 Capping Cylindrical Concrete Specimens

ASTM Standards:

C 125 Terminology Related to Concrete and Concrete Aggregates

ACI Standards:

309 R Guide for Consolidation of Concrete

WAQTC:

TM 2 Sampling Freshly Mixed Concrete

WSDOT:

Quality Systems Manual Verification Procedure 2-Single Use Molds

WSDOT FOP for WAQTC TM 2 Sampling Freshly Mixed Concrete

[1] This FOP is based on AASHTO T 23-08

3. Terminology

For definitions of terms used in this practice, refer to Terminology ASTM C 125.

4. SIGNIFICANCE AND USE

4.1 This practice provides standardized requirements for making, curing, protecting, and transporting concrete test specimens under field conditions.

4.2 If the specimens are made and standard cured, as stipulated herein, the resulting strength test data where the specimens are tested are able to be used for the following purposes:

4.2.1 Acceptance testing for specified strength,

4.2.2 Checking the adequacy of mixture proportions for strength,

4.2.3 Quality control.

4.3 If the specimens are made and field cured, as stipulated herein, the resulting strength test data when the specimens are tested are able to be used for the following purposes:

4.3.1 Determination of whether a structure is capable of being put in service.

4.3.2 Comparison with test results of standard cured specimens or with test results from various in-place test methods,

4.3.4 Adequacy of curing and protection of concrete in the structure, or,

4.3.5 Form or shoring removal time requirements,

5. APPARATUS

5.1 Molds, General — Refer to AASHTO T 23

5.2 Cylinder: *Molds for casting concrete test specimens shall conform to the requirements of M 205, and* shall come from an approved shipment as verified by the WSDOT Quality Systems Manual Verification Procedure No. 2.

5.3 Beam Molds — Refer to WSDOT Test Method T 808.

5.4 Tamping Rod — Two sizes are specified as indicated in Table 1. Each shall be a round, straight steel rod with at least the tamping end rounded to a hemispherical tip of the same diameter as the rod. Both ends may be rounded if preferred.

	Rod Dimensions	
Diameter of Cylinder in (mm.)	**Diameter, in (mm.)**	**Length of Rod, in (mm.)**
4(100)	⅜ (10)	12 (300)
6(150)	⅝ (16)	20 (500)

a Rod tolerances length ±4 in. (100 mm) and diameter ± $^{1}/_{16}$ in (2 mm).

Tamping Rod Requirements
Table 1

5.5 Vibrators — Internal vibrators shall be used. The vibrator frequency shall be at least 7,000 vibrations per minute at 150 Hz while the vibrator is operating in the concrete. The diameter of a round vibrator shall be no more than one-fourth the diameter of the cylinder mold or one-fourth the width of the beam mold. Other shaped vibrators shall have a perimeter equivalent to the circumference of an appropriate round vibrator. The combined length of the vibrator shaft and vibrating element shall exceed the depth of the section being vibrated by at least 3 in. (75 mm). The vibrator frequency shall be checked periodically.

Note 1: For information on size and frequency of various vibrators and a method to periodically check vibrator frequency, see ACI 309R.

5.6 Mallet — A mallet with a rubber or rawhide head weighing 1.25 ± 0.50 lb [0.57 ± 0.23 kg] shall be used.

5.7 Small Tools — Tools and items that may be required are shovels, pails, trowels, wood float, metal float, blunted trowels, straightedge, feeler gauge, scoops, and rules.

5.8 Sampling and Mixing Receptacle — The receptacle shall be a suitable heavy gage metal pan, wheelbarrow, or flat, clean non-absorbent mixing board of sufficient capacity to allow easy remixing of the entire sample with a shovel or trowel.

5.9 Cure Box- The cure box shall be capable of maintaining temperatures between 60°F and 80°F. The box shall also be capable of maintaining an environment that does not allow moisture loss from the concrete cylinders.

5.10 Temperature Measuring Device- The temperature measuring device shall be capable of recording the minimum and maximum temperature within a 24 hr period. The thermometer shall be capable of reading from 32°F to 150°F (0°C to 65°C) with an accuracy of 1.8°F (1.0°C).

6. TESTING REQUIREMENTS

Testing for determining the compressive strength at 28 days shall require a set of two specimens made from the same sample.

6.1 *Compressive Strength Specimens* — Compressive strength specimens shall be cylinders cast and allowed to set in an upright position. The length shall be twice the diameter. The cylinder diameter shall be at least three times the nominal maximum size of the coarse aggregate. The standard specimen shall be the 4 by 8-in. (100 by 200-mm) cylinder when the nominal maximum size of the coarse aggregate does not exceed 1 in. (25 mm). When the nominal maximum size of the coarse aggregate exceeds 1 in. (25 mm) the specimens shall be made with 6 by 12 in. (150 by 300 mm) cylinders. **Mixing of cylinder sizes for a particular concrete mix design is not permitted on a project.** When the nominal maximum size of the coarse aggregate exceeds 2 in (50 mm), the concrete sample shall be treated by wet sieving through a 2 in (50 mm) sieve as described in FOP for WAQTC TM 2. Contact the Materials Laboratory for directions.

Note 2: The nominal maximum size is the smallest standard sieve opening through which the entire amount of aggregate is permitted to pass.

Note 3: When molds in SI units are required and not available, equivalent inch-pound unit size molds should be permitted.

6.2 Flexural Strength Specimens

Refer to WSDOT Test Method T 808

7. SAMPLING CONCRETE

7.1 The samples used to fabricate test specimens under this standard shall be obtained in accordance with FOP for WAQTC TM-2 unless an alternative procedure has been approved.

7.2 Record the identification of the sample with respect to the location of the concrete represented and the time of casting.

7.3 Cylinders shall be made using fresh concrete from the same sample as the slump, air content and temperature tests. Material from the slump, air content, and unit weight tests cannot be reused to construct cylinders.

8. SLUMP, AIR CONTENT, AND TEMPERATURE

As required, perform the following tests prior to making cylinders:

8.1 Slump —FOP FOR AASHTO T 119.

8.2 Air Content —FOP for AASHTO T 152 or FOP for AASHTO T 196.

8.3 Temperature —FOP for AASHTO T 309.

8.4 Unit Weight — AASHTO T 121

9. MOLDING Cylinders

9.1 Place of Molding — Mold cylinders on a level, rigid horizontal surface, free of vibration and other disturbances, at a place as near as practicable to the location where they are to be stored.

9.2 Casting the Concrete — Place the concrete in the mold using a scoop, blunted trowel, or shovel. Select each scoopful, trowelful, or shovelful of concrete from the mixing pan to ensure that it is representative of the batch. Remix the concrete in the mixing pan with a shovel or trowel to prevent segregation during the molding of specimens. Move the scoop, trowel, or shovel around the perimeter of the mold opening when adding concrete so the concrete is uniformly distributed within each layer with a minimum of segregation. Further distribute the concrete by use of the tamping rod prior to the start of consolidation. In placing the final layer, the operator shall attempt to add an amount of concrete that will exactly fill the mold after consolidation. Underfilled molds shall be adjusted with representative concrete during consolidation of the top layer. Overfilled molds shall have excess concrete removed.

9.2.1 Number of Layers — Make specimens in layers as indicated in Table 2 or 3.

Cylinders: Diameter, in (mm)	Number of Layers of Approximately Equal Depth	Number of Roddings per Layer
Cylinders:		
Diameter, in. (mm)		
4 (100)	2	25
6 (150)	3	25

Molding Requirements by Rodding
Table 2

Cylinders: Diameter, in (mm)	Number of Layers	Number of Vibrator Insertions per Layer	Approximate Depth of Layer, mm (in.)
Cylinders:			
Diameter, in. (mm)			
4 (100)	2	1	one-half depth of specimen
6 (150)	2	2	one-half depth of specimen

Molding Requirements by Vibration
Table 3

9.2.2 Select the proper tamping rod from 5.4 and Table 1 or the proper vibrator from 5.5. If the method of consolidation is rodding, determine molding requirements from Table 2. If the method of consolidation is vibration, determine molding requirements from Table 3.

9.3 Consolidation:

9.3.1 Method of Consolidation — Preparation of satisfactory cylinders require different methods of consolidation. The methods of consolidation are rodding and vibration. Base the selection of the method of consolidation on slump, unless the method is stated in the specifications under which the work is being performed. Rod or vibrate concretes with slumps greater than 1 in. (25 mm). Vibrate concretes with slumps less than or equal to 1 in. (25 mm). Concretes of such low water content that they cannot be properly consolidated by the method herein, or requiring other sizes and shapes of specimens to represent the product or structure, are not covered by this method. Specimens for such concretes shall be made in accordance with the requirements of R 39 with regards to specimen size and shape and method of consolidation.

9.3.2 Rodding — Place the concrete in the mold, in the required number of layers of approximately equal volume. Rod each layer with the rounded end of the rod using the required number of roddings specified in Table 2. Rod the bottom layer throughout its depth. Distribute the strokes uniformly over the cross section of the mold. For each layer, allow the rod to penetrate through the layer being rodded and into the layer below approximately 25 mm (1 in.).

After each layer is rodded, tap the outsides of the mold lightly 10 to 15 times with the open hand mallet, or rod, to close any holes left by rodding and to release any large air bubbles that may have been trapped.

9.3.3 Vibration — Maintain a uniform time period for duration of vibration for the particular kind of concrete, vibrator, and specimen mold involved. The duration of vibration required will depend upon the workability of the concrete and the effectiveness of the vibrator. Usually, sufficient vibration has been applied as soon as the surface of the concrete has become relatively and large air bubbles cease to break through the top surface. Continue vibration only long enough to achieve proper consolidation of the concrete. (See Note 4.) Fill the molds and vibrate in the required number of approximately equal layers. Place all the concrete for each layer in the mold before starting vibration of that layer. Compacting the specimen, insert the vibrator slowly and do not allow it to rest on the bottom or sides of the mold. Slowly withdraw the vibrator so that no large air pockets are left in the specimen. When placing the final layer, avoid overfilling by more than ¼ in. (6 mm).

Note 4 — Generally, no more than 5 s of vibration should be required for each insertion to adequately consolidate concrete with a slump greater than 3 in. (75 mm). Longer times may be required for lower slump concrete, but the vibration time should rarely have to exceed 10 s per insertion.

9.3.3.1 *Cylinders* — The number of insertions of a vibrator per layer is given in Table 3. When more than one insertion per layer is required, distribute the insertion uniformly within each layer. Allow the vibration to penetrate through the layer being vibrated, and into the layer below, approximately 1 in. (25 mm). After each layer is vibrated, tap the outsides of the mold lightly 10 to 15 times with the open hand, mallet, or rod, to close any holes left by rodding and to release any large air bubbles that may have been trapped.

9.3.3.2 *Beam* — Refer to WSDOT Test Method T 808.

9.4 *Finishing* — After consolidation, strike off excess concrete from the surface. Perform all finishing with the minimum manipulation necessary to produce a flat even surface that is level with the rim or edge of the mold and that has no depressions or projections larger than ⅛ in. (3.2 mm). Place lid on cylinder.

10. CURING

10.1 *Standard Curing*—Standard curing is the curing method used when the specimens are made and cured for the purposes stated in 4.2.

10.1.1 *Storage*—If specimens cannot be molded at the place where they will receive initial curing, immediately after finishing, move the specimens to an initial curing place for storage. The supporting surface on which specimens are stored shall be level to within ¼ in. per ft (20 mm per m.). If cylinders in the single-use molds are moved, lift and support the cylinders from the bottom of the molds with a large trowel or similar device. If the top surface is marred during movement to place of initial storage, immediately refinish.

10.1.2 *Initial Curing*—Immediately after molding and finishing, the specimens shall be stored in a cure box for a period 24 ± 8 hours, unless Contractor provides initial curing information for final set.

For concrete with a specified strength less than 6000 psi the cure temperature shall be between 60°F and 80°F and for concrete with specified strengths of 6000 psi and higher the cure temperature shall be between 68°F and 78°F.

A minimum/maximum thermometer shall be mounted on the cure box such that the thermometer reads the internal temperature of the box but is visible from the outside. Keep a record of the minimum and maximum temperatures at intervals of 24 hours during the initial curing time.

Do not exceed the capacity of the cure box. When concrete is placed at more than one location simultaneously, each location must have its own cure box.

Once concrete cylinders are placed in the cure box, the cure box shall not be moved until the cylinders are ready to be transported to the final cure location (See 10.1.3).

10.1.3 *Transportation of specimens to final cure location*- Prior to transporting, cure and protect specimens as required in Section 9. Specimens shall not be transported until at least 8 h after final set. (See Note 5) During transporting, protect the specimen with suitable cushioning material to prevent damage from jarring and transport in an upright position. During cold weather, protect the specimens from freezing with suitable insulation material. Prevent moisture loss during transportation by use of tight-fitting plastic caps on plastic molds. Transportation time shall not exceed 4 h.

Note 5: If a specimen does not attain final set within 32 hours, it is to remain in place until final set is reached. The time of final set shall be provided by the concrete producer. After final set is reached, it can then be transported.

10.1.4 *Final Curing*:

10.1.4.1 *Cylinders*—Upon completion of initial curing and within 30 minutes after removing the molds, cure specimens with free water maintained on their surfaces at all times at a temperature of 73 ± 3°F (23 ± 2°C) using water storage tanks or moist rooms complying with the requirements of Specification M 201, except when capping with sulfur mortar capping compound and immediately before testing. When capping with sulfur mortar capping compounds, the ends of the cylinder shall be dry enough to preclude the formation of steam or foam pockets under or in cap larger than ¼ in (6 mm.) as described in T 231. For a period not to exceed 3 h immediately prior to test, standard curing temperature is not required provided free moisture is maintained on the cylinders and ambient temperature is between 68 to 80°F (20 and 30°C).

10.1.4.2 *Beams*—Refer to WSDOT Test Method T 808.

10.2 *Field Curing*—Field curing is the curing method used for the specimens made for the purposes stated in 4.3.

10.2.1 *Cylinders* — Store cylinders in or on the structure as near to the point of deposit of the concrete represented as possible. Protect all surfaces of the cylinders from the elements in as near as possible the same way as the formed work. Provide the cylinders with the same temperature and moisture environment as the structural work. Test the specimens in the moisture condition resulting from the specified curing treatment. To meet these conditions, specimens made for the purpose of determining when a structure is capable of being put in service shall be removed from the molds at the time of removal of form work.

10.2.2 *Beams* — Refer to WSDOT Test Method T 808.

11. TRANSPORTATION OF SPECIMENS TO LABORATORY

See Section 10.1.3

12 REPORT

12.1 Report the following information to the laboratory that will test the specimens:

12.1.1 Identification number;

12.1.2 Location of concrete represented by the samples;

12.1.3 Date, time, and name of individual molding specimens;

12.1.4 Slump, air content, and concrete temperature, test results and results of any other tests on the fresh concrete and any deviations from referenced standard test methods, and

12.1.5 Record all information required using the Materials Automatic Tracking System (MATS) electronic Concrete Transmittal or for those not having access to MATS use WSDOT Form 350-009 Concrete Cylinder Transmittal

Performance Exam Checklist

Making and Curing Concrete Test Specimens in the Field
FOP for AASHTO T 23

Participant Name ______________________________ Exam Date _______________

Procedure Element	Yes	No
1. The tester has a copy of the current procedure on hand?	❒	❒
2. Molds placed on a level, rigid, horizontal surface free of vibration?	❒	❒
3. Making of specimens begun within 15 minutes of sampling?	❒	❒
4. Concrete placed in the mold, moving a scoop or trowel around the perimeter of the mold to evenly distribute the concrete as discharged?	❒	❒
5. Mold filled in correct number of layers, attempting to exactly fill the mold on the last layer?	❒	❒
6. Each layer rodded throughout its depth 25 times with hemispherical end of rod, uniformly distributing strokes?	❒	❒
7. Bottom layer rodded throughout its depth?	❒	❒
8. Middle and top layers rodded, each throughout their depths, and penetrate into the underlying layer?	❒	❒
9. Sides of the mold tapped 10-15 times after rodding each layer?	❒	❒
10. Strike off excess concrete, and finished the surface with a minimum of manipulation?	❒	❒
11. Specimens covered with non-absorbent, nonreactive cap or plate?	❒	❒

First attempt: Pass ❒ Fail ❒ Second attempt: Pass ❒ Fail ❒

Signature of Examiner

This checklist is derived, in part, from copyrighted material printed in ACI CP-1, published by the American Concrete Institute.

Comments:

WSDOT FOP FOR WAQTC/AASHTO T 27/T 11[1]

Sieve Analysis of Fine and Coarse Aggregates

Significance

Sieve analyses are performed on aggregates used in roadway bases and in portland cement and asphalt cement concretes. Sieve analyses reveal the size makeup of aggregate particles – from the largest to the smallest. A gradation curve or chart showing how evenly or unevenly the sizes are distributed between largest and smallest is created in this test. How an aggregate is graded has a major impact on the strength of the base or on the properties and performance of concrete. In portland cement concrete (PCC), for example, gradation influences shrinkage and shrinkage cracking, pumpability, finishability, permeability, and other characteristics.

Scope

This procedure covers sieve analysis in accordance with AASHTO T 27 and materials finer than No. 200 (75 µm) in accordance with AASHTO T 11. The procedure combines the two test methods.

Sieve analyses determines the gradation or distribution of aggregate particles within a given sample in order to determine compliance with design and production standards.

Accurate determination of material smaller than No. 200 (75 µm) cannot be made with AASHTO T 27 alone. If quantifying this material is required, it is recommended that AASHTO T 27 be used in conjunction with AASHTO T 11. Following AASHTO T 11, the sample is washed through a No. 200 (75 µm) sieve. The amount of material passing this sieve is determined by comparing dry sample masses before and after the washing process.

This procedure covers sieve analysis in accordance with AASHTO T 27 and materials finer than No. 200 (75 µm) in accordance with AASHTO T 11. The procedure includes two method choices, A, and B.

Note: All Field Operating Procedures (FOP's) referred to in this procedure are WSDOT FOP's.

Apparatus

- Balance or scale: Capacity sufficient for the masses shown in Table 2, accurate to 0.1 percent of the sample mass or better and conform to the requirements of AASHTO M 231.
- Sieves – Meeting the requirements of AASHTO M 92.
- Mechanical sieve shaker – Meeting the requirements of AASHTO T 27.
- Suitable drying equipment (see FOP for AASHTO T 255)
- Containers and utensils: A pan or vessel of a size sufficient to contain the sample covered with water and to permit vigorous agitation without loss of any part of the sample or water
- Optional Mechanical washing device

[1] This FOP is based on WAQTC FOP for AASHTO T 27/T 11 and has been modified per WSDOT standards. To View the redline modifications, contact WSDOT Quality Systems Manager (360) 709-5497.

Sample Sieving

In all procedures it is required to shake the sample over nested sieves. Sieves are selected to furnish information required by specification. The sieves are nested in order of decreasing size from the top to the bottom and the sample, or a portion of the sample, is placed on the top sieve. The sample may also be sieved in increments.

Sieves are shaken in a mechanical shaker for the minimum time determined to provide complete separation for the sieve shaker being used.

Time Evaluation

WSDOT has deleted this section.

Overload Determination

Additional sieves may be necessary to provide other information, such as fineness modulus, or to keep from overloading sieves. The sample may also be sieved in increments.

Additional sieves may be necessary to provide other information, such as fineness modulus, or to keep from overloading sieves. The sample may also be sieved in increments. For sieves with openings smaller than No. 4 (4.75 mm), the mass retained on any sieve shall not exceed 4 g/in^2 (7 kg/m^2) of sieving surface. For sieves with openings No. 4 (4.75 mm) and larger, the mass, in grams shall not exceed the product of 2.5 x (sieve opening in mm) x (effective sieving area). See Table 1.

Sieve Size US inches (mm)		8 φ (203)	12 φ (305)	12 x 12 (305 x 305)	14 x 14 (350 x 350)	16 x 24 (372 x 580)
		Sieving Area m^2				
		0.0285	0.0670	0.0929	0.1225	0.2158
3½	(90)	*	15.1	20.9	27.6	48.5
3	(75)	*	12.6	17.4	23.0	40.5
2½	(63)	*	10.6	14.6	19.3	34.0
2	(50)	3.6	8.4	11.6	15.3	27.0
1½	(37.5)	2.7	6.3	8.7	11.5	20.2
1	(25.0)	1.8	4.2	5.8	7.7	13.5
¾	(19.0)	1.4	3.2	4.4	5.8	10.2
⅝	(16.0)	1.1	2.7	3.7	4.9	8.6
½	(12.5)	0.89	2.1	2.9	3.8	6.7
⅜	(9.5)	0.67	1.6	2.2	2.9	5.1
¼	(6.3)	0.44	1.1	1.5	1.9	3.4
No. 4	(4.75)	0.33	0.80	1.1	1.5	2.6
Less than	(No. 4)	0.20	0.47	0.65	0.86	1.5
Note: Sample sizes above are in kilograms to covert: to grams multiple by 1,000. To convert to pounds multiple by 2.2.						

Maximum Allowable Mass of Material Retained on a Sieve, kg

Table 1

Sample Preparation

Obtain samples in accordance with the FOP for AASHTO T 2 and reduce to the size shown in Table 2 in accordance with the FOP for AASHTO T 248.

If the gradation sample is obtained from FOP for AASHTO T-308, the Ignition Furnace, proceed to Procedure Method A, Step 2.

Nominal Maximum		Minimum Dry Mass	
Size* in.	**(mm)**	**lb**	**kg**
US No. 4	(4.75)	1	0.5
¼	(6.3)	2	1
⅜	(9.5)	2	1
½	(12.5)	5	2
⅝	(16.0)	5	2
¾	(19.0)	7	3
1	(25.0)	13	6
1¼	(31.5)	17	7.5
1½	(37.5)	20	9
2	(50)	22	10
2½	(63)	27	12
3	(75)	33	15
3½	(90)	44	20

Sample Sizes for Aggregate Gradation Test
Table 2

* For aggregate, the nominal maximum size, (NMS) is the largest standard sieve opening listed in the applicable specification, upon which any material is permitted to be retained. For concrete aggregate, NMS is the smallest standard sieve opening through which the entire amount of aggregate is permitted to pass.

Note: For an aggregate specification having a generally unrestrictive gradation (i. e. wide range of permissible upper sizes), where the source consistently fully passes a screen substantially smaller than the maximum specified size, the nominal maximum size, for the purpose of defining sampling and test specimen size requirements may be adjusted to the screen, found by experience to retain no more than 5% of the materials.

WSDOT Note 1: These sample sizes are standard for aggregate testing but, due to equipment restraints, samples may need to be partitioned into several "subsamples." See Method A.

Overview

Method A - This method is the preferred method of sieve analysis for HMA aggregate.

- Determine dry mass of original sample
- Wash through a No. 200 (75 µm) sieve
- Determine dry mass of washed sample
- Sieve material

Method B

- Determine dry mass of original sample
- Wash through a No. 200 (75 µm) sieve
- Determine dry mass of washed sample
- Sieve coarse material
- Determine mass of fine material
- Reduce fine portion
- Determine mass of reduced portion
- Sieve fine portion

Procedure Method A

1. Dry the sample in accordance with the FOP for AASHTO T 255, and record to the nearest 0.1 percent of total mass or better.
2. When the specification requires that the amount of material finer than No. 200 (75 µm) be determined, do Step 3 through Step 9 – otherwise, skip to Step 10.

   WSDOT Note 2: If the applicable specification requires that the amount passing the No. 200 (75 µm) sieve be determined on a portion of the sample passing a sieve smaller than the nominal maximum size of the aggregate, separate the sample on the designated sieve and determine the mass of the material passing that sieve to 0.1 percent of the mass of this portion of the test sample. Use the mass as the original dry mass of the test sample.
3. Nest a sieve, such as a No. 10 (2 mm), above the No. 200 (75 µm) sieve.
4. Place the test sample in a container and add sufficient water to cover it.

   WSDOT requires the use of a detergent, dispersing agent, or other wetting solution when washing a sample from FOP for AASHTO T 308, an ignition furnace sample.

   WSDOT Note 3: A detergent, dispensing agent, or other wetting solution may be added to the water to assure a thorough separation of the material finer than the No. 200 (75 µm) sieve from the coarser particles. There should be enough wetting agent to produce a small amount of suds when the sample is agitated. Excessive suds may overflow the sieves and carry material away with them.
5. Agitate vigorously to ensure complete separation of the material finer than No. 200 (75 µm) from coarser particles and bring the fine material into suspension above the coarser material. When using a mechanical washing device, exercise caution to not degrade the sample.
6. Immediately pour the wash water containing the suspended and dissolved solids over the nested sieves, being careful not to pour out the coarser particles.
7. Add a second change of water to the sample remaining in the container, agitate, and repeat Step 6. Repeat the operation until the wash water is reasonably clear.
8. Return all material retained on the nested sieves to the container by flushing into the washed sample.

   WSDOT Note 4: A suction device may be used to extract excess water from the washed sample container. Caution will be used to avoid removing any material greater than the No. 200.

9. Dry the washed aggregate in accordance with the FOP for AASHTO T 255, and then cool prior to sieving. Record the dry mass.
10. Select sieves to furnish information required by the specifications. Nest the sieves in order of decreasing size from top to bottom and place the sample, or a portion of the sample, on the top sieve.
11. Place sieves in mechanical shaker and shake for a minimum of 10 minutes, or the minimum time determined to provide complete separation if this time is greater than 10 minutes for the sieve shaker being used.
12. Determine the individual or cumulative mass retained on each sieve and the pan to the nearest 0.1 percent or 0.1 g.

    WSDOT Note 5: Use coarse wire brushes to clean the No. 40 (425 µm) and larger sieves, and soft bristle brushes for smaller sieves.

Calculations

The total mass of material after sieving should be verified with the mass before sieving. If performing T 11 with T 27 this would be the dry mass after wash. If performing just T 27 this would be the original dry mass. When the masses before and after sieving differ by more than 0.3 percent do not use the results for acceptance purposes. When performing the gradation from HMA using T 308, the masses before and after sieving shall not differ by more than 0.2%.

Calculate the total percentages passing, individual or cumulative percentages retained, or percentages in various size fractions to the nearest 0.1 percent by dividing the masses for Method A, or adjusted masses for Methods B and C, on the individual sieves by the total mass of the initial dry sample. If the same test sample was first tested by T 11, use the total dry sample mass prior to washing in T 11 as the basis for calculating all percentages. Report percent passing as indicated in the "Report" section at the end of this FOP.

Percent Retained:

Where:
IPR = Individual Percent Retained
CPR = Cumulative Percent Retained
M = Total Dry Sample mass before washing
IMR = Individual Mass Retained OR Adjusted Individual mass from Methods B or C
CMR= Cumulative Mass Retained OR Adjusted Individual mass From Methods B or C

$$IPR = \frac{IMR}{M} \# 100 \text{ OR } CPR = \frac{CMR}{M} \# 100$$

OR

Percent Passing (Calculated):

Where:
PP = Percent Passing
PPP = Previous Percent Passing
PP = PPP-IPR OR PP = 100-CPR

Calculate cumulative percent retained on and passing each sieve on the basis of the dry mass of total sample, before washing. This will include any material finer than No. 200 (75 µm) that was washed out.

Divide the cumulative masses, or the corrected masses, on the individual sieves by the total mass of the initial dry sample (prior to washing) to determine the percent retained on and passing each sieve. Calculate the percent retained on and passing each sieve. Report percent passing as indicated in the “Report” section at the end of this FOP.

Example

Dry mass of total sample, before washing: 3214.0 g

Dry mass of sample, after washing out the No. 200 (75 µm) minus: 3085.1 g

For the ½ sieve:

Cumulative Mass retained on ½" sieve = 161.0 g

Cumulative % retained = $\frac{161.0}{3214.0} \# 100 = 5.0\%$ retained

% passing = 100-5.0 = 95% passing ½" sieve

Sieve Size in. (mm)		Cumulative Mass Retained g	Cumulative Percent Retained	Reported Percent Passing*
¾	(19.0)	0	0	100
½	(12.5)	161.0	5.0	95
⅜	(9.5)	642.0	20.0	80
No. 4	(4.75)	1118.3	34.8	65
**No. 6	(3.35)	1515.2		
No. 10	(2.0)	1914.7	59.6	40
No. 40	(0.425)	2631.6	81.9	18
No. 80	(0.210)	2862.7	89.1	11
No. 200	(0.075)	3051.1	94.9	5.1
Pan		3086.4		

* Report No. 200 (75 µm) sieve to 0.1 percent. Report all others to 1 percent.

** Intermediate sieve used to prevent overloading the U. S. No. 10 sieve.

Gradation on All Screens

Test Validation: 3086.4 – 3085.1/3085.1 x 100 = 0.04 % which is within the 0.3 percent requirement and the results can be used for acceptance purposes.

Procedure Method B

1. Perform steps 1 thru 9 from the "Procedure Method A" then continue as follows:
2. Select sieves to furnish information required by the specifications. Nest the sieves in order of decreasing size from top to bottom through the No. 4 (4.75 mm) with a pan at the bottom to retain the minus No. 4 (4.75 mm). (See Table 1.)
3. Place sieves in mechanical shaker and shake for a minimum of 10 minutes, or the minimum time determined to provide complete separation if this time is greater than 10 minutes for the sieve shaker being used.
4. Determine the individual or cumulative mass retained on each sieve and the pan to the nearest 0.1 percent or 0.1 g. Ensure that all material trapped in the openings of the sieve are cleaned out and included in the mass retained. (See Note 5)
5. Determine the mass retained on each sieve to the nearest 0.1 percent of the total mass or better.
6. Determine the mass of the material in the pan [minus No. 4 (4.75 mm)].
7. Reduce the minus No. 4 (4.75 mm) using a mechanical splitter in accordance with the FOP for AASHTO T 248 to produce a sample with a mass of 500 g minimum. Determine and record the mass of the minus No. 4 (4.75 mm) split.
8. Select sieves to furnish information required by the specifications. Nest the sieves in order of decreasing size from top to bottom through the No. 200 (75 µm) with a pan at the bottom to retain the minus No. 200 (75 µm).
9. Place sieves in mechanical shaker and shake for a minimum of 10 minutes, or the minimum time determined to provide complete separation if this time is greater than 10 minutes for the sieve shaker being used.
10. Determine the individual or cumulative mass retained on each sieve and the pan to the nearest 0.1 percent or 0.1 g. Ensure that all material trapped in the openings of the sieve are cleaned out and included in the mass retained. (See Note 5)

Calculations

Compute the "Adjusted Cumulative Mass Retained" of the size increment of the original sample as follows when determining "Cumulative Mass Retained":

Divide the cumulative masses, or the corrected masses, on the individual sieves by the total mass of the initial dry sample (prior to washing) to determine the percent retained on and passing each sieve. Calculate the percent retained on and passing each sieve. Report percent passing as indicated in the "Report" section at the end of this FOP.

When material passing the No. 4 (4.75 mm) sieve is split and only a portion of that is tested, the proportionate share of the amount passing the No. 200 (75 µm) sieve must be added to the sample mass to obtain a corrected test mass. This corrected test mass is used to calculate the gradation of the material passing the No. 4 (4.75 mm) sieve.

$$C = \left(\frac{M_1}{M_2} \times B\right) + D$$

where:

C = Total cumulative mass retained of the size increment based on a total sample

M_1 = mass of fraction finer than No. 4 (4.75 mm) sieve in total sample

M_2 = mass of reduced portion of material finer than No. 4 (4.75 mm) sieve actually sieved

B = cumulative mass of the size increment in the reduced portion sieved.

D = cumulative mass of plus No. 4 (4.75 mm) portion of sample.

Example:

Dry mass of total sample, before washing: 3214.0 g

Dry mass of sample, after washing out the No. 200 (75 µm) minus: 3085.1 g

Sieve Size in. (mm)	Cumulative Mass Retained g	Cumulative Percent Retained	Reported Percent Passing*
¾ (19.0)	0	0	100
½ (12.5)	161.0	5.0	95
⅜ (9.50)	642.0	20.0	80
No. 4 (4.75)	1118.3	34.8	65

Gradation on Coarse Screens

Pan = 1968.0

Test Validation : 1118.3 + 1968.0 – 3085.1/3085.1 x 100 = 0.04% which is within the 0.3 percent requirement and the results can be used for acceptance purposes.

The actual mass of material passing the No. 4 (4.75 mm) sieve and retained in the pan is 1968.0 g. This is M_1.

The pan (1968.0 grams) was reduced in accordance with the FOP for AASHTO T 248, so that at least 500 g are available. In this case, the mass determined was 512.8 g. This is M_2.

Sieve Size in. (mm)	Cumulative Mass Retained (g)
No. 4 (4.75)	0
No. 10 (2.00)	207.5
No. 40 (0.425)	394.3
No. 80 (0.210)	454.5
No. 200 (0.075)	503.6
Pan	512.8

Gradation on Fine Screens

Test Validation: 512.8 - 512.8/512.8 = 0.0 % which is within the 0.3 percent requirement and the results can be used for acceptance purposes.

For the No. 10 sieve:

M_1 = 1968.0g

M_2 = 512.8g

B = 207.5g

D = 1118.3g

$$C = \left(\frac{M_1}{M_2} \times B\right) + D = \left(\frac{1968.0g}{512.8g} \times 207.5g\right) + 1118.3g = 1914.7g$$

% retained $\frac{1914.7g}{3214.0g} = 59.6\%$

% passing = 100-59.6=40.4% reported as 40%

Final Gradation on All Screens

Sieve Size in. (mm)		Cumulative Mass Retained g	Adjusted Cumulative Mass Retained g	Cum. Percent Retained	Reported Percent Passing*
¾	(19.0)	0	0	0	100.0
½	(12.5)	161.1	161.1	5.0	95
⅜	(9.5)	642.5	642.5	20.0	80
No. 4	(4.75)	1118.3	1118.3	34.8	65
No. 10	(2.0)	207.5 x 3.838 + 1118.3	1914.7	59.6	40
No. 40	(0.425)	394.3 x 3.838 + 1118.3	2631.6	81.6	18
No. 80	(0.210)	454.5 x 3.838 + 1118.3	2862.7	89.1	11
No. 200	(0.075)	503.6 x 3.838 + 1118.3	3051.1	94.9	5.1
Pan		512.8 x 3.838 + 1118.3	3086.4		

* Report No. 200 (75 µm) sieve to 0.1 percent. Report all others to 1 percent.

Alternative Method B

As an alternate method to account for the fact that only a portion of the minus No. 4 (4.75 mm) material was sieved, multiply the fine screen "Percent Passing" values by the percent passing the No. 4 (4.75 mm) sieve obtained in the coarse screen procedure, 65 percent in this case.

The mass retained in the pan must be corrected to include the proper percent of No. 200 (.075 mm) minus material washed out.

Divide the cumulative masses, or the corrected masses, on the individual sieves by the corrected pan mass of the initial dry sample (prior to washing) to determine the percent retained on and passing each sieve. Calculate the percent retained on and passing each sieve. Report percent passing as indicated in the "Report" section at the end of this FOP.

Dry mass of total sample, before washing: 3214.0 g

Dry mass of sample, after washing out the No. 200 (75 µm) minus: 3085.1 g

Amount of No. 200 (75 µm) minus washed out: 3214.0 g – 3085.1 g = 128.9 g

Gradation on Coarse Screens

Sieve Size in. (mm)	Cumulative Mass Retained g	Cumulative Percent Retained	Reported Percent Passing*
¾ (19.0)	0	0	100
½ (12.5)	161.0	5.0	95
⅜ (9.50)	642.0	20.0	80
No. 4 (4.75)	1118.3	34.8	65

Pan = 1968.0

Test Validation : $\frac{1118.3 + 1968.0 - 3085.1}{3085.1 \# 100} = 0.04\%$

which is within the 0.3 percent requirement and the results can be used for acceptance purposes.

The actual mass of material passing the No. 4 (4.75 mm) sieve and retained in the pan is 1968.0 g. This is M_3.

The pan (1968.0 grams) was reduced in accordance with the FOP for AASHTO T 248, so that at least 500 g are available. In this case, the mass determined was 512.8 g. This is M_4.

Corrected pan mass = $M_4 + \frac{(M_4)(C_1)}{M_3}$

Where:

M_4 = mass retained in the pan from the split of the No. 4 (4.75 mm) minus.

M_3 = mass of the No. 4 (4.75 mm) minus of entire sample, not including No. 200 (.075 mm) minus washed out.

C_1 = mass of No. 200 (.075 mm) minus washed out.

Sieve Size in. (mm)	Cumulative Mass Retained (g)	Cumulative Percent Retained	Percent Passing
No. 4 (4.75)	0	0	100.0
No. 10 (2.00)	207.5	38.0	62.0
No. 40 (0.425)	394.3	72.2	27.8
No. 80 (0.210)	454.5	83.2	16.8
No. 200 (0.075)	503.6	92.2	7.8
Pan	512.8		

The corrected pan mass is the mass used to calculate the percent retained for the fine grading.

Example:

$M_4 = 512.8g$

$M_3 = 1968.0g$

$C_1 = 128.9g$

Corrected pan mass = $512.8g + \frac{(512.8g)(128.9g)}{1968.0g} = 546.4g$

For the No. 10 sieve:

Mass of No. 10 sieve = 207.5g

Corrected Pan Mass = 546.4g

Cumulative % retained = $\frac{207.5g}{546.4g} = 38.0\%$

% passing = 100-38.0 = 62.0%

Adjusted % passing No. 10 = % passing No. 10 x % No. 4 = 62.0 x 0.65 = 40%

Sieve Size in. (mm)		Adjustment	Reported Percent Passing*
¾	(19.0)		100
½	(12.5)		95
⅜	(9.5)		80
No. 4	(4.75)	100 x .65 =	65
No. 10	(2.00)	62.0 x .65 =	40
No. 40	(0.425)	27.8 x .65 =	18
No. 80	(0.210)	16.8 x .65 =	11
No. 200	(0.075)	7.8 x .65 =	5.1
* Report No. 200 (75 µm) sieve to 0.1 percent. Report all others to 1 percent			

Final Gradation on All Screens

SAMPLE CALCULATION FOR FINENESS MODULUS

Fineness Modulus (FM) is used in determining the degree of uniformity of aggregate gradation in PCC mix designs. It is an empirical number relating to the fineness of the aggregate. The higher the FM, the coarser the aggregate. Values of 2.40 to 3.00 are common for FA in PCC.

The FM is the sum of the percentages retained on specified ⅜″ (9.5 mm), No. 4 (4.75 mm), 2.36 mm (No. 8), 1.18 mm (No. 16), 0.60 mm (No. 30), 0.30 mm (No. 50), and 0.15 mm (No. 100) divided by 100 gives the FM.

The following example is for WSDOT Class 2 Sand:

WSDOT Class 2 Sand				
Sieve	**Size**	**% Passing**	**% Retained**	**% Retained on Specified Sieves**
⅜ in.	9.5 mm	100	0	0
No. 4	4.75 mm	100	0	0
No. 8	2.36 mm	87	13	13
No. 16	1.18 mm	69	31	31
No. 30	0.60 mm	44	56	56
No. 50	0.30 mm	18	82	82
No. 100	0.15 mm	4	96	96
				= 278
				FM = 2.78

REPORT

Results shall be reported on standard forms approved for use by the agency. Depending on the agency, this may include:

- Cumulative mass retained on each sieve
- Cumulative percent retained on each sieve
- Percent passing and retained on each sieve shall be reported to the nearest 1 percent except for the percent passing the U.S. No. 200 (75 µm) sieve, which shall be reported to the nearest 0.1 percent
- FM to the nearest 0.01 percent for WSDOT Class 2 Sand

Report results using WSDOT Form 422-020, or other report approved by the State Materials Engineer.

Performance Exam Checklist

WAQTC FOP FOR AASHTO T 27/T 11
SIEVE ANALYSIS OF FINE AND COARSE AGGREGATES

Participant Name ________________________ Exam Date ______________

Procedure Element	Yes	No
1. The tester has a copy of the current procedure on hand?	❒	❒
2. All equipment is functioning according to the test procedure, and if required, has the current calibration/verification tags present?	❒	❒
3. Minimum sample mass meets requirement of Table 1 or from FOP for AASHTO T308?	❒	❒
4. Test sample dried to a constant mass by FOP for AASHTO T 255?	❒	❒
5. Test sample cooled and mass determined to nearest 0.1 percent of mass?	❒	❒
6. Sample placed in container and covered with water? (If specification requires that the amount of material finer than the No. 200 sieve is to be determined.)	❒	❒
7. Dispersing Agent used for HMA?	❒	❒
8. Contents of the container vigorously agitated?	❒	❒
9. Complete separation of coarse and fine particles achieved?	❒	❒
10. Wash water poured through nested sieves such as No. 10 and No. 200?	❒	❒
11. Operation continued until wash water is reasonably clear?	❒	❒
12. Material retained on sieves returned to washed sample?	❒	❒
13. Washed aggregate dried to a constant mass by FOP for AASHTO T 255?	❒	❒
14. Washed aggregate cooled and mass determined to nearest 0.1 percent of mass?	❒	❒
15. Sample placed in nest of sieves specified? (Additional sieves may be used to prevent overloading as allowed in FOP.)	❒	❒
16. Material sieved in verified mechanical shaker for minimum of 10 minutes or for the minimum verified time whichever is longer?	❒	❒
17. Mass of residue on each sieve determined to 0.1 percent of mass?	❒	❒
18. Total mass of material after sieving agrees with mass before sieving to within 0.3 percent, or 0.2 percent for HMA (per FOP for AASHTO T308)?	❒	❒
19. Percentages calculated to the nearest 0.1 percent and reported to the nearest whole number, except No. 200 - reported to the nearest 0.1 percent?	❒	❒
20. Percentage calculations based on original dry sample mass?	❒	❒
21. Calculations performed properly? If material passing No. 4 sieve is split and only a portion is tested, calculation as noted in FOP performed properly?	❒	❒

First attempt: Pass ❒ Fail ❒ Second attempt: Pass ❒ Fail ❒

Signature of Examiner ______________________________

Comments:

WSDOT FOP for AASHTO T 99[1]

Moisture-Density Relations of Soils Using a 5.5-lb (2.5-kg) Rammer and a 12-in. (305-mm) Drop

1. SCOPE

1.1 These methods of test are intended for determining the relation between the moisture content and density of soils compacted in a mold of a given size with a 5.5-lb (2.5-kg) rammer dropped from a height of 12 in. (305 mm). Four alternate procedures are provided as follows:

Method A
A 4-in. (101.60-mm) mold: Soil material passing a No. 4 (4.75-mm) sieve Sections 3 and 4.

Method B
A 6-in. (152.40-mm) mold: Soil material passing a No. 4 (4.75-mm) sieve Sections 5 and 6.

Method C
A 4-in. (101.60-mm) mold: Soil material passing a ¾-in. (19.0-mm) sieve Sections 7 and 8.

Method D
A 6-in. (152.40-mm) mold: Soil material passing a ¾-in. (19.0-mm) sieve Sections 9 and 10.

The preferred method of WSDOT is to use Method A.

WSDOT recommends that the bulk specific gravity of coarse aggregate be determined.

Native soils within the contract limits to be used for embankment construction and/or backfill material do not require the sampling by a qualified tester. For material that requires gradation testing such as but not limited to manufactured aggregates and Gravel Borrow, a qualified testers shall be required for sampling.

1.2 The method to be used should be indicated in the specifications for the material being tested. If no method is specified, the provisions of Method A shall govern.

1.3. This test method applies to soils mixtures that have ~~40%~~ 30% or less retained on the No. 4 (4.75 mm) sieve, when Method A or B is used and 30% or less retained on the ¾-in. (19.0-mm) sieve, when Method C or D is used. The material retained on these sieves shall be defined as oversized particles (coarse particles).

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[1] This FOP is based on AASHTO T 99-09 and has been modified per WSDOT standards. To view the redline modifications, contact WSDOT Quality Systems Manager at (360) 709-5412.

1.4. If the test specimen contains oversize particles, and the test specimen is used for field density compaction control, corrections must be made according to ~~T 224~~ SOP 615 to compare the total field density with the compacted specimen density. The person or agency specifying this method shall specify a minimum percentage below which correction for oversize need not be applied. If no minimum percentage is specified, correction shall be applied to samples with more than 5% by weight of oversize particles.

1.5. If the specified oversized maximum tolerances are exceeded, other methods of compaction control must be used.

Note 1: One method for the design and control of the compaction of such soils is to use a test fill to determine the required degree of compaction and a method to obtain that compaction. Then use a method specification to control the compaction by specifying the type and size of compaction equipment, the lift thickness and the number of passes.

1.6. The following applies to all specified limits in this standard: For the purposes of determining conformance with these specifications, an observed value or a calculated value shall be rounded off "to the nearest unit" in the last right-hand place of figures used in expressing the limiting value, in accordance with ASTM E 29.

1.7. The values stated in SI units are to be regarded as the standard.

2. Referenced Documents

2.1. *AASHTO Standards:*

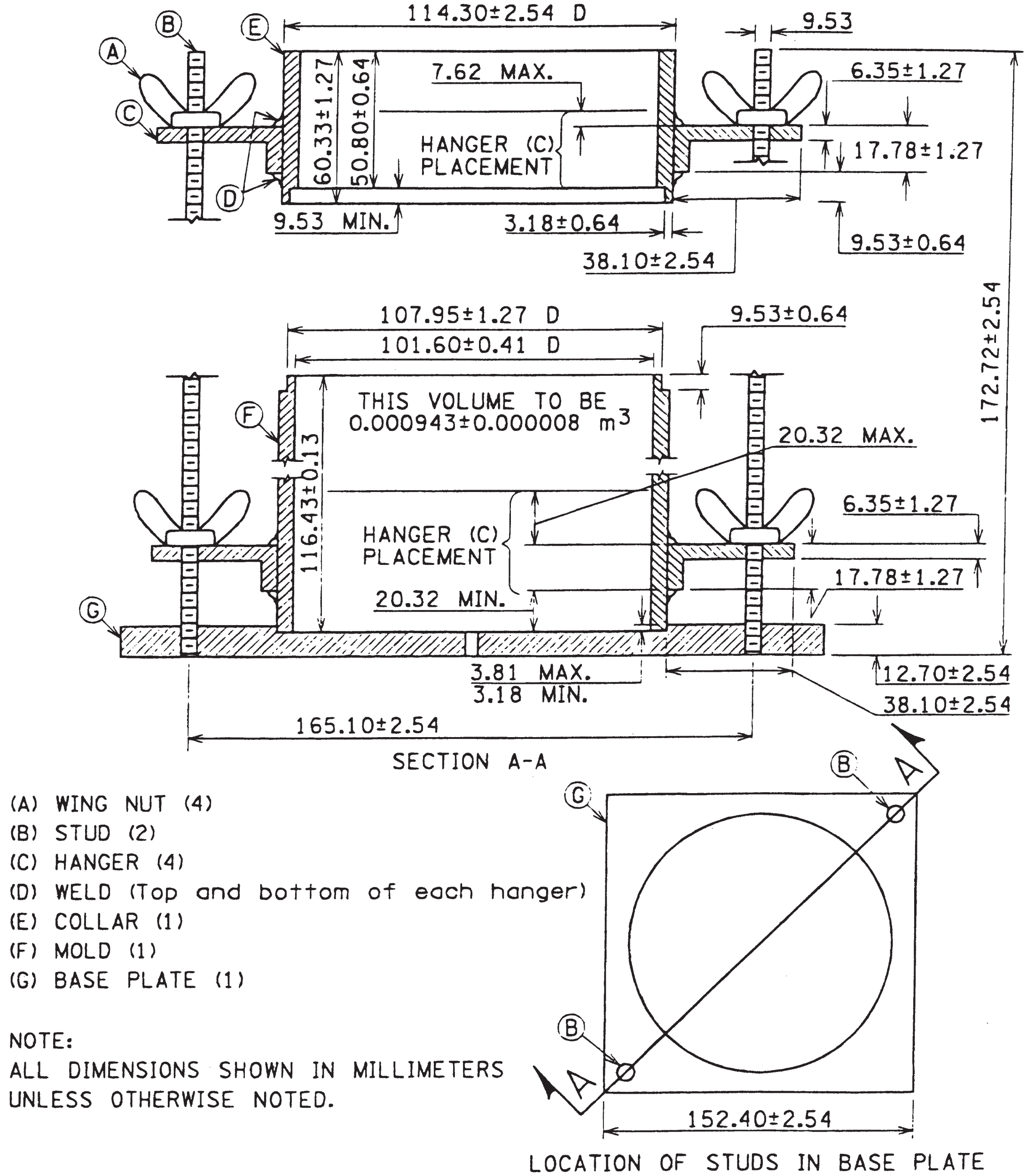
- M 92, Wire-Cloth Sieves for Testing Purposes
- M 231, Weighing Devices Used in the Testing of Materials
- T 19/T 19M, Bulk Density ("Unit Weight") and Voids in Aggregate
- T 224, Correction for Coarse Particles in the Soil Compaction Test
- T 255, Total Evaporable Moisture Content of Aggregate by Drying
- T 265, Laboratory Determination of Moisture Content of Soils

2.2. *ASTM Standard:*

- D 2168, Calibration of Laboratory Mechanical-Rammer Soil Compactors
- E 29, Using Significant Digits in Test Data to Determine Conformance with Specifications

3. APPARATUS

3.1 Molds — The molds shall be solid-wall, metal cylinders manufactured with dimensions and capacities shown in Sections 3.1.1 and 3.1.2 below. They shall have a detachable collar assembly approximately 2.375 in. (60 mm) in height, to permit preparation of compacted specimens of soil-water mixtures of the desired height and volume. The mold and collar assembly shall be so constructed that it can be fastened firmly to a detachable base plate made of the same material (Note 2). The base plate shall be plane to 0.005 in. as shown in Figures 1 and 2.

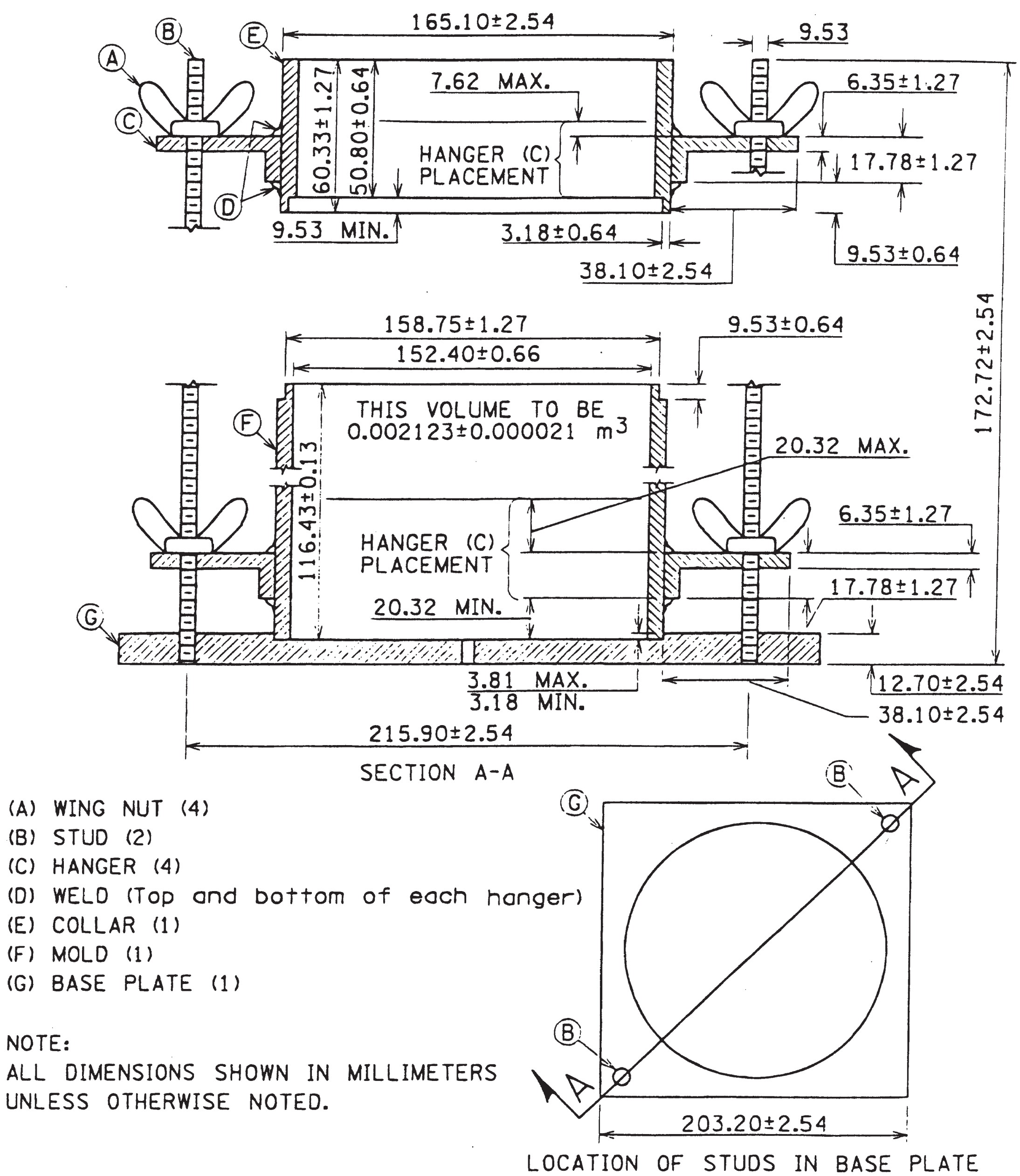


Dimensional Equivalents

mm	in.	mm	in.
3.18 ± 0.64	0.125 ± 0.025	50.80 ± 0.64	2.000 ± 0.025
3.81	0.150	60.33 ± 1.27	2.375 ± 0.050
6.35 ± 1.27	0.250 ± 0.050	101.60 ± 0.41	4.000 ± 0.016
7.62	0.300	107.95 ± 1.27	4.250 ± 0.050
9.53 ± 0.64	0.375 ± 0.025	114.30 ± 2.54	4.500 ± 0.100
12.70 ± 2.54	0.500 ± 0.100	116.43 ± 0.13	4.584 ± 0.005
17.78 ± 1.27	0.700 ± 0.050	152.40 ± 2.54	6.000 ± 0.100
20.32	0.800	165.10 ± 2.54	6.500 ± 0.100
38.10 ± 2.54	1.500 ± 0.100	172.72 ± 2.54	6.800 ± 0.100

$0.000943 \pm 0.000008\ m^3$ $\quad$ $1/30 \pm 0.0003\ ft^3$

Cylindrical Mold and Base Plate (101.6-mm mold)
Figure 1



Dimensional Equivalents

mm	in.	mm	in.
3.18 ± 0.64	0.125 ± 0.025	50.80 ± 0.64	2.000 ± 0.025
3.81	0.150	60.33 ± 1.27	2.375 ± 0.050
6.35 ± 1.27	0.250 ± 0.050	116.43 ± 0.13	4.584 ± 0.005
7.62	0.300	152.40 ± 0.66	6.000 ± 0.026
9.53 ± 0.64	0.375 ± 0.025	158.75 ± 1.27	6.250 ± 0.050
12.70 ± 2.54	0.500 ± 0.100	165.10 ± 2.54	6.500 ± 0.100
17.78 ± 1.27	0.700 ± 0.050	172.72 ± 2.54	6.800 ± 0.100
20.32	0.800	203.23 ± 2.54	8.000 ± 0.100
38.10 ± 2.54	1.500 ± 0.100	215.90 ± 2.54	8.500 ± 0.100

$0.002123 \pm 0.000021\ m^3$ $1/13.33 \pm 0.00075\ ft^3$

Cylindrical Mold and Base Plate (152.4-mm mold)
Figure 2

Note 2: Alternate types of molds with capacities as stipulated herein may be used, provided the test results are correlated with those of the solid-wall mold on several soil types and the same moisture-density results are obtained. Records of such correlation shall be maintained and readily available for inspection, when alternate types of molds are used.

3.1.1 A 4-in. (101.6-mm) mold having a capacity of 1/30 (0.0333) ± 0.0003 cu. ft. (0.000943 ± 0.000008 m^3) with an internal diameter of 4.000 ± 0.016 in. (101.60 ± 0.41 mm) and a height of 4.584 ± 0.005 in. (116.43 ± 0.13 mm) (Figure 1).

3.1.2 A 6-in. (152.4-mm) mold having a capacity of 1/13.33 (0.07500) ± 0.00075 cu. ft. (0.002124 ± 0.000021 m^3) with an internal diameter of 6.000 ± 0.026 in. (152.40 ±0.66 mm) and a height of 4.584 ± 0.005 in. (116.43 ± 0.13 mm) (Figure 2).

3.1.3 Molds Out of Tolerance Due to Use — A mold that fails to meet manufacturing tolerances after continued service may remain in use provided those tolerances are not exceeded by more than 50 percent; and the volume of the mold, calibrated in accordance with Section 8 (Calibration of Measure) of T 19/T 19M, for Unit Mass of Aggregate, is used in the calculations.

3.2 Rammer

3.2.1 Manually Operated — Metal rammer with a mass of 5.5 ± 0.02 lb (2.495 ± 0.009 kg), and having a flat circular face of 2.000-in. (50.80-mm) diameter with a manufacturing tolerance of 0.01 in. (± 0.25 mm). The in-service diameter of the flat circular face shall be not less than 1.985 in. (50.42 mm). The rammer shall be equipped with a suitable guide-sleeve to control the height of drop to a free fall of 12.00 ± 0.06 in. (305 ± 2 mm) above the elevation of the soil. The guide-sleeve shall have at least 4 vent holes, no smaller than ⅜-in. (9.5-mm) diameter spaced approximately 90 degrees (1.57 rad) apart and approximately ¾ in. (19 mm) from each end; and shall provide sufficient clearance so the free fall of the rammer shaft and head is unrestricted.

3.2.2 Mechanically Operated — A metal rammer which is equipped with a device to control the height of drop to a free fall of 12.00 ± 0.06 in. (305 ± 2 mm) above the elevation of the soil and uniformly distributes such drops to the soil surface (Note 3). The rammer shall have a mass of 5.5 ± 0.02 lb (2.495 ± 0.009 kg), and have a flat circular face of 2.000-in. (50.80 mm) diameter with a manufactured tolerance of 0.01 in. (± 0.25 mm). The in-service diameter of the flat circular face shall be not less than 1.985 in. (50.42 mm). The mechanical rammer shall be calibrated by ASTM D 2168.

Note 3: It may be impractical to adjust the mechanical apparatus so the free fall is 12 in. (305 mm) each time the rammer is dropped, as with the manually operated rammer. To make the adjustment of free fall, the portion of loose soil to receive the initial blow should be slightly compressed with the rammer to establish the point of impact from which the 12 in. (305 mm) drop is determined. Subsequent blows on the layer of soil being compacted may all be applied by dropping the rammer from a height of 12 in. (305 mm) above the initial-setting elevation; or, when the mechanical apparatus is designed with a height adjustment for each blow, all subsequent blows should have a rammer free fall of 12 in. (305 mm) measured from the elevation of the soil as compacted by the previous blow. A more detailed calibration procedure for laboratory mechanical-rammer soil compactors can be found in ASTM D 2168.

3.2.3 Rammer Face — The circular face rammer shall be used but a sector face may be used as an alternative provided the report shall indicate type of face used other than the 2-in. (50.8-mm) circular face and it shall have an area equal to that of the circular face rammer.

3.3 Sample Extruder (for Solid-Walled Molds Only) — A jack, lever, frame, or other device adopted for the purpose of extruding compacted specimens from the mold.

3.4 Balances and Scales — A balance or scale conforming to the requirements of AASHTO M 231, Class G 20. Also, a balance conforming to the requirements of AASHTO M 231, Class G 2.

Note 4: The capacity of the metric balance or scale should be approximately 11.5 kg when used to weigh the 6-in. (152.40-mm) mold and compacted, moist soil; however, when the 4-in. (101.60-mm) mold is used, a balance or scale of lesser capacity than the 11.5 kg may be used, if the sensitivity and readability is 5 g.

3.5 Drying Oven — A thermostatically controlled drying oven capable of maintaining a temperature of 230 ± 9°F (110 ± 5°C) for drying moisture samples.

3.6 Straightedge — A hardened-steel straightedge at least 10 in. (250 mm) in length. It shall have one beveled edge, and at least one longitudinal surface (used for final trimming) shall be plane within 0.01 in. per 10 in. (0.250 mm per 250 mm) (0.1 percent) of length within the portion used for trimming the soil (Note 5).

Note 5: The beveled edge may be used for final trimming if the edge is true within a tolerance of 0.01 in. per 10 in. (0.250 mm per 250 mm) (0.1 percent) of length; however, with continued use, the cutting edge may become excessively worn and not suitable for trimming the soil to the level of the mold. The straightedge should not be so flexible that trimming the soil with the cutting edge will cause a concave soil surface.

3.7 Sieves — 2-in. (50-mm), ¾-in. (19.0-mm), and No. 4 (4.75-mm) sieves conforming to the requirements of M 92.

3.8 Mixing Tools — Miscellaneous tools such as mixing pan, spoon, trowel, spatula, etc., or a suitable mechanical device for thoroughly mixing the sample of soil with increments of water.

3.9 Containers — Suitable containers made of material resistant to corrosion and not subject to change in mass or disintegration on repeated heating and cooling. Containers shall have close-fitting lids to prevent loss of moisture from samples before initial mass determination and to prevent absorption of moisture from the atmosphere following drying and before final mass determination. One container is needed for each moisture content determination.

METHOD A

4. SAMPLE

4.1 If the soil sample is damp when received from the field, dry it until it becomes friable under a trowel. Drying may be in air or by use of a drying apparatus which is maintained at a temperature not exceeding 140°F (60°C). Then thoroughly break up the aggregations in such a manner as to avoid reducing the natural size of individual particles.

4.2 Sieve an adequate quantity of the representative pulverized soil over the No. 4 (4.75-mm) sieve. Discard the coarse material, if any, retained on the No. 4 (4.75-mm) sieve.

4.3 Select a representative sample, with a mass of approximately 7 lb (3 kg) or more, of the soil prepared as described in Sections 4.1 and 4.2.

Note 6: When developing a compaction curve for free draining soils, such as uniform sands and gravels, where seepage occurs at the bottom of the mold and base plate, taking a representative moisture content sample from the mixing bowl may be preferred in order to determine the amount of moisture available for compaction.

5. PROCEDURE

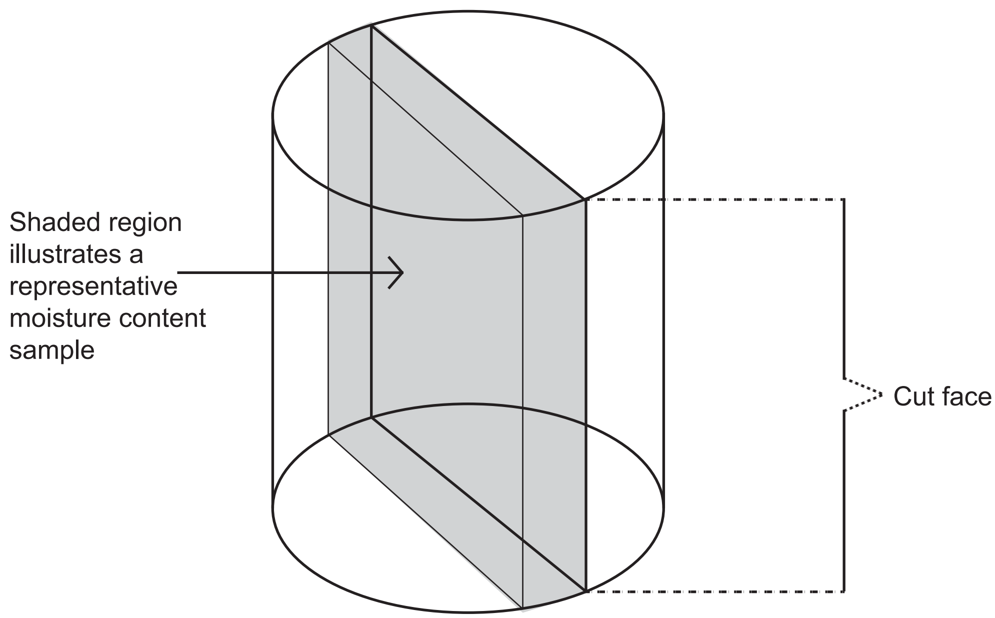
5.1 Thoroughly mix the selected representative sample with sufficient water to dampen it to approximately four percentage points below optimum moisture content.

5.2 Form a specimen by compacting the prepared soil in the 4-in. (101.60-mm) mold (with collar attached) in three approximately equal layers to give a total compacted depth of about 5 in. (125 mm). Prior to compaction, place the loose soil into the mold and spread into a layer of uniform thickness. Lightly tamp the soil prior to compaction until it is not in a loose or fluffy state, using either the manual compaction rammer or similar device having a face diameter of approximately 2 in. (50 mm). Following compaction of each of the first two layers, any soil adjacent to the mold walls that has not been compacted or extends above the compacted surface shall be trimmed using a knife or other suitable device, and be evenly distributed on top of the layer. Compact each layer by 25 uniformly distributed blows from the rammer dropping free from a height of 12 in. (305 mm) above the elevation of the soil when a sleeve-type rammer is used, or from 12 in. (305 mm) above the approximate elevation of compacted soil when a stationary mounted type of rammer is used. During compaction, the mold shall rest firmly on a dense, uniform, rigid, and stable foundation or base. This base shall remain stationary during the compaction process (Note 7).

Note 7: Each of the following has been found to be a satisfactory base on which to rest the mold during compaction of the soil: A block of concrete, with a mass not less than 200 lb (90 kg), supported by a relatively stable foundation; a sound concrete floor; and for field application, such surfaces as are found in concrete box culverts, bridges, and pavements.

5.2.1 Following compaction, remove the extension collar, carefully trim the compacted soil even with the top of the mold by means of the straightedge, and determine the mass of the mold and moist soil in kilograms to the nearest 5 grams, or determine the mass in pounds to the nearest 0.01 pounds. Calculate the wet density, as described in Section 12.2 or 12.3.

5.3 Remove the material from the mold and slice vertically through the center. Take a representative sample of the material from the entire face of one of the cut faces. The minimum mass of the sample shall be in accordance with the Table 1. Weigh sample immediately and dry in accordance with T 255 or T 265, to determine the moisture content, and record the results.



Representative Moisture Content Sample Selection
Figure 3

Maximum Particle Size	Minimum Mass of Sample, g
No. 40 (0.425-mm) sieve	100
No. 4 (4.75-mm) sieve	100
½ in. (12.5-mm)	300
1 in. (25.0-mm)	500
2 in. (50-mm)	1000

Table 1

5.4 Thoroughly break up the remaining portion of the molded specimen until it will pass a No. 4 (4.75-mm) sieve as judged by eye, and add to the remaining portion of the sample being tested. Add water in sufficient amount to increase the moisture content of the soil one to two percentage points (water content increments should not exceed 2.5 percent except when heavy clay soils or organic soils exhibiting flat elongated curves are encountered, the water content increments may be increased to a maximum of 4 percent), and repeat the above procedure for each increment of water added. Continue this series of determinations until there is either a decrease or no change in the wet unit mass, W_1, per cubic foot (cubic meter) of the compacted soil (Note 8).

Note 8: This procedure has been found satisfactory in most cases. However, in instances where the soil material is fragile in character and will reduce significantly in grain size due to repeated compaction, and in cases where the soil is a heavy-textured clayey material into which it is difficult to incorporate water, a separate and new sample shall be used in each compaction test. In these cases, separate samples shall be thoroughly mixed with amounts of water sufficient to cause the moisture contents of the samples to vary by approximately two percentage points. The moisture points selected shall bracket the optimum moisture content, thus providing samples which, when compacted, will increase in mass to the maximum density and then decrease in mass. The samples of soil-water mixtures shall be placed in covered containers and allowed to stand for not less than 12 hours before making the moisture-density test.

5.4.1 In instances where the soil material is fragile in character and will be reduced significantly in grain size by repeated compaction, a separate and new sample shall be used in each compaction test.

METHOD B

6. SAMPLE

6.1 Select the representative sample in accordance with Section 3.3, except that it shall have a mass of approximately 16 lb (7 kg).

7. PROCEDURE

7.1 Follow the same procedure as described for Method A in Section 4, except for the following: Form a specimen by compacting the prepared soil in the 6-in. (152.4-mm) mold (with collar attached) in three approximately equal layers to give a total compacted depth of about 5 in. (125 mm), each layer being compacted by 56 uniformly distributed blows from the rammer. Calculate the wet density, as described in Section 12.2 or 12.3.

METHOD C

8. SAMPLE

8.1 If the soil sample is damp when received from the field, dry it until it becomes friable under a trowel. Drying may be in air or by use of a drying apparatus which is maintained at a temperature not exceeding 140°F (60°C). Then thoroughly break up the aggregations in such a manner as to avoid reducing the natural size of individual particles.

8.2 Sieve an adequate quantity of the representative pulverized soil over the 19.0-mm sieve. Discard the coarse material, if any, retained on the ¾ in. (19.0-mm) sieve (Note 9).

Note 9: If it is advisable to maintain the same percentage of coarse material (passing a 2 in. (50-mm) sieve and retained on a No. 4 (4.75-mm) sieve) in the moisture-density sample as in the original field sample, the material retained on the ¾ in. (19.0-mm) sieve shall be replaced as follows: Sieve an adequate quantity of the representative pulverized soil over the 2 in. - ¾ in. (50- and 19.0-mm) sieves. Determine the mass of the material passing the 2 in. (50-mm) sieve and retained on the ¾ in. (19.0-mm) sieve and replace it with an equal mass of material passing the ¾ in. (19.0-mm) sieve and retained on the No. 4 (4.75-mm) sieve. Take the material for replacement from the remaining portion of the sample.

8.3 Select a representative sample, having a mass of approximately 11 lb (5 kg) or more, of the soil prepared as described in Sections 8.1 and 8.2.

9. PROCEDURE

9.1 Thoroughly mix the selected representative sample with sufficient water to dampen it to approximately 4 percentage points below optimum moisture content.

9.2 Form a specimen by compacting the prepared soil in the 4-in. (101.60-mm) mold (with collar attached) in three approximately equal layers to give a total compacted depth of about 5 in. (125 mm). Prior to compaction, place the loose soil into the mold and spread into a layer of uniform thickness. Lightly tamp the soil prior to compaction until it is not in a loose or fluffy state, using either the manual compaction rammer or similar device having a face diameter of approximately 2 in. (50 mm). Following compaction of each of the first two layers, any soil adjacent to the mold walls that has not been compacted or extends above the compacted surface shall be trimmed using a knife or other suitable device, and be evenly distributed on top of the layer. Compact each layer by 25 uniformly distributed blows from the rammer dropping free from a height of 12 in. (305 mm) above the elevation of the soil when a sleeve-type rammer is used, or from 12 in. (305 mm) above the approximate elevation of each finely compacted layer when a stationary mounted type rammer is used. During compaction, the mold shall rest firmly on a dense, uniform, rigid and stable foundation (Note 7).

9.2.1 Following compaction, remove the extension collar, carefully trim the compacted soil even with the top of the mold by means of the straightedge. Holes developed in the surface by removal of coarse material shall be patched with smaller sized material. Determine the mass of the mold and moist soil in kilograms to the nearest 5 grams, or determine the mass in pounds to the nearest 0.01 pounds. Calculate the wet density, as described in Section 12.2 or 12.3.

9.3 Remove the material from the mold and slice vertically through the center. Take a representative sample of the material fro one of the cut faces, determine the mass immediately and dry in accordance with T 255 or T 265, to determine the moisture content, and record the results.

9.4 Thoroughly break up the remainder of the material until it will pass a ¾ in. (19.0-mm) sieve and 90 percent of the soil aggregations will pass a No. 4 (4.75-mm) sieve as judged by eye, and add to the remaining portion of the sample being tested. Add water in sufficient amounts to increase the moisture content of the soil sample by one or two percentage points, and repeat the above procedure for each increment of water added. Continue this series of determinations until there is either a decrease or no change in the wet mass, W_1, per cubic foot (cubic meter) of compacted soil (Note 8).

METHOD D

10. SAMPLE

10.1 Select the representative sample in accordance with Section 8.3 except that it shall have a mass of approximately 25 lb (11 kg).

11. PROCEDURE

11.1 Follow the same procedure as described for Method C in Section 9, except for the following: Form a specimen by compacting the prepared soil in the 6-in. (152.4-mm) mold (with collar attached) in three approximately equal layers to give a total compacted depth of about 5 in. (125 mm), each layer being compacted by 56 uniformly distributed blows from the rammer. Calculate the wet density, as described in Section 12.2 or 12.3.

CALCULATIONS AND REPORT

12. CALCULATIONS

12.1 The mold factor can be related to the volume of the mold as follows:

$$F = 1 / V \tag{1}$$

where:
F = mold factor; and
V = volume of mold.

12.2 The wet density can be determined using the mold factor. For masses recorded in kilograms, the unit of wet density is kilograms per cubic meter of compacted soil. For masses recorded in pounds, the unit of wet density is pounds per cubic foot of compacted soil.

$$W1 = (A - B) \times F \tag{2}$$

where:
A = mass of compacted specimen and mold;
B = mass of mold;
F = mold factor as given in Table 3; and
$W1$ = wet density

Mold Factor		
Method	**For masses recorded in kilograms**	**For masses recorded in pounds**
A	1060	30
B	471	13.3
C	1060	30
D	471	13.3

For used molds in compliance with Section 3.1.3, determine the mold factor in accordance with Section 3.1.3 and Equation 1.

Mold Factors for Molds in Compliance with Sections 3.1.1 or 3.1.2
Table 3

12.3. Alternatively, the wet density can be determined using the mold volume. For masses recorded in kilograms, the unit of wet density is kilograms per cubic meter of compacted soil. For masses recorded in pounds, the unit of wet density is pounds per cubic foot of compacted soil.

$$W_1 = (A - B)/V \qquad (3)$$

where:

V = mold volume as given in Section 3.1.1 for Methods A and C, or Section 3.1.2 for Methods B and D. For used molds in compliance with Section 3.1.3, determine the mold volume in accordance with Section 3.1.3.

12.4. The dry density is related to the wet density as follows:

$$W = \frac{W_1}{w + 100} \times 100 \qquad (4)$$

where:

w = moisture content (percent) of the specimen, as determined by T 265; and
W = dry density, in kilograms per cubic meter of compacted soil, or pounds per cubic foot of compacted soil.

13. MOISTURE-DENSITY RELATIONSHIP

13.1 The calculations in Section 12 shall be made to determine the moisture content and corresponding oven-dry unit mass (density) in kilograms per cubic meter or pounds per cubic foot of the compacted samples. The oven-dry densities (unit mass) of the soil shall be plotted as ordinates and the corresponding moisture content as abscissas.

13.2 Optimum Moisture Content — When the densities and corresponding moisture contents for the soil have been determined and plotted as indicated in Section 13.1, it will be found that by connecting the plotted points with a smooth line, a curve is produced. The moisture content corresponding to the peak of the curve shall be termed the “optimum moisture content” of the soil under the above compaction.

13.3 Maximum Density — The oven-dry density in pounds per cubic foot (kilograms per cubic meter) of the soil at optimum moisture content shall be termed “maximum density” under the above compaction.

Note: In general, a more accurate curve is produced when a minimum of three points are plotted on the dry side and two points are plotted on the wet side of the curve.

14. REPORT

14.1 The report shall include the following:

14.1.1 The method used (Method A, B, C, or D).

14.1.2 The optimum moisture content, as a percentage, to the nearest whole number.

14.1.3 The maximum density in pounds per cubic foot to the nearest whole number (kilograms per cubic meter to the nearest 10 kg/m^3).

14.1.4 In Methods C and D indicate if the material retained on the ¾ in. (19.0-mm) sieve was removed or replaced.

14.1.5 Type of face if other than 2 in. (50.8 mm) circular.

15. PRECISION STATEMENT

See AASHTO T-99 for Precision.

Tester Qualification Practical Exam Checklist

Moisture-Density Relations of Soils Using a 5.5-lb (2.5-kg) Rammer and a 12-in. (305-mm) Drop
FOP for AASHTO T 99

Participant Name ______________________________ Exam Date ______________

Procedure Element	Yes	No
1. The tester has a copy of the current procedure on hand?	❐	❐
2. All equipment is functioning according to the test procedure, and if required, has the current calibration/verification tags present?	❐	❐
Sample Preparation		
1. If damp, sample dried in air or drying apparatus, not exceeding 140°F (60°C)?	❐	❐
2. Sample pulverized and adequate amount sieved over the No. 4 (4.75 mm) sieve?	❐	❐
3. Material retained on the sieve discarded?	❐	❐
4. Sample passing the sieve has appropriate mass?	❐	❐
Procedure		
1. Sample mixed with water to approximately 4 percent below expected optimum moisture content?	❐	❐
2. Layer of soil placed in mold with collar attached?	❐	❐
3. Mold placed on rigid and stable foundation?	❐	❐
4. Lightly tamp soil in mold?	❐	❐
5. Soil compacted with 25 blows?	❐	❐
6. Scrape sides of mold and evenly distributed on top of the layer?	❐	❐
7. Soil placed and compacted in three equal layers?	❐	❐
8. No more than ½ inch of soil above the top of the bottom portion of the mold?	❐	❐
9. Collar removed and soil trimmed to top of mold with straightedge?	❐	❐
10. Mass of mold and contents determined to appropriate precision?	❐	❐
11. Wet mass of specimen multiplied by mold factor to obtain wet density?	❐	❐
12. Soil removed from mold using sample extruder when applicable?	❐	❐
13. Soil sliced vertically through center?	❐	❐
14. Moisture sample removed from the entire face of one of the cut faces?	❐	❐
15. Sample weighed immediately and mass recorded?	❐	❐

Tester Qualification Practical Exam Checklist (continued)

Procedure

16. Moisture sample mass per Table 1? ❐ ❐
17. Sample dried and water content determined according to AASHTO T 255 or T 265? ❐ ❐
18. Remainder of material from mold broken up to about passing sieve size and added to remainder of original test sample? ❐ ❐
19. Water added to increase moisture content in approximately 2 percent increments? ❐ ❐
20. Steps 2 through 15 repeated for each increment of water added? ❐ ❐
21. If soil is plastic (clay types):
    a. Sample mixed with water varying moisture content by approximately 2 percent, bracketing the optimum moisture content? ❐ ❐
    b. Samples placed in covered containers and allowed to stand for at least 12 hours ❐ ❐
22. Process continued until wet density either decreases or stabilizes? ❐ ❐
23. Water content and dry density calculated for each sample? ❐ ❐
24. All calculations performed correctly? ❐ ❐

First attempt: Pass ❐ Fail ❐ Second attempt: Pass ❐ Fail ❐

Signature of Examiner ________________________________

Comments:

WSDOT FOP for AASHTO T 106[1]

Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or (50-mm) Cube Specimens)

1. SCOPE

1.1 This test method covers determination of the compressive strength of hydraulic cement mortars, using 2-in. or (50-mm) cube specimens.

Note 1: Test Method C 349 provides an alternative procedure for this determination (not to be used for acceptance tests).

1.2 The values stated in SI units are to be regarded as the standard. The values in parentheses are for information only.

1.3 Values in SI units shall be obtained by measurement in SI units or by appropriate conversion, using the Rules for Conversion and Rounding given in Standard IEEE/ASTM SI 10, of measurements made in other units.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. REFERENCED DOCUMENTS

2.1 *AASHTO Standards:*

M 85 Portland Cement

M 152 Mixing Rooms, Flow Table for Use in Tests of Hydraulic Cement

M 201 Moist Cabinets, Moist Rooms, and Water Storage Tanks Used in the Testing of Hydraulic Cements and Concretes

M 240 Blended Hydraulic Cements

M 295 Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete

M 302 Ground Granulated Blast-Furnace Slag for Use in Concrete and Mortars

R11 Recommended Practice for Indicating Which Places of Figures Are to be Considered Significant in Specified Limiting Values

T 105 Chemical Analysis of Hydraulic Cement

T 162 Mechanical Mixing of Hydraulic Cement Pastes and Mortars of Plastic Consistency

[1] This Test Method is based on AASHTO T 106-09

2.2 *ASTM Standards*:

C 91 Masonry Cement

C 349 Test Method for Compressive Strength of Hydraulic Cement Mortars (Using Portions of Prisms Broken in Flexure)

C 670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

C 778 Specification for Standard Sand 2

C 1005 Specification for Weights and Weighing Devices for Use in Physical Testing of Hydraulic Cements

C 1157 Hydraulic Cement

C 1328 Plastic (Stucco) Cement

C 1329 Mortar Cement

IEEE/ASTM SI 10 Standard for Use of the International System of Units (SI): The Modern Metric System

3. SUMMARY OF TEST METHOD

3.1 The mortar used consists of one part cement and 2.75 parts of sand proportioned by mass. Portland or air-entraining portland cements are mixed at specified water/cement ratios. Water content for other cements is sufficient to obtain a flow of 110 ± 5 in 25 drops of the flow table. Two-inch or (50-mm) test cubes are compacted by tamping in two layers. The cubes are cured 24 hours in the molds and stripped and immersed in lime water until tested.

4. SIGNIFICANCE AND USE

4.1 This test method provides a means of determining the compressive strength of hydraulic cement and other mortars and results may be used to determine compliance with specifications. Further, this test method is referenced by numerous other specifications and test methods. Caution must be exercised in using the results of this test method to predict the strength of concretes.

5. APPARATUS

5.1 *Standard Masses and Balances,* shall conform to the requirements of ASTM C 1005. The balance device shall be evaluated for precision and bias at a total load of 2000 g.

5.2 *Glass Graduates*, of suitable capacities (preferably large enough to measure the mixing water in a single operation) to deliver the indicated volume at 20°C. The permissible variation shall be ±2 mL. These graduates shall be subdivided to at least 5 mL, except that the graduation lines may be omitted for the lowest 10 mL for a 250-mL graduate and for the lowest 25 Ml of a 500-mL graduate. The main graduation lines shall be circles and shall be numbered. The least graduations shall extend at least one seventh of the way around, and intermediate graduations shall extend at least one fifth of the way around.

5.3 *Specimen Molds*, for the 2-in. or (50-mm) cube specimens shall be tight fitting. The molds shall have not more than three cube compartments and shall be separable into not more than two parts. The parts of the molds when assembled shall be positively held together. The molds shall be made of hard metal not attacked by the cement mortar. For new molds the Rockwell hardness number of the metal shall be not less than 55 HRB. The sides of the molds shall be sufficiently rigid to prevent spreading or warping. The interior faces of the molds shall be plane surfaces and shall conform to the tolerances of Table 1.

	2 in. Cube Molds		50-mm Cube Molds	
Parameter	**New**	**In Use**	**New**	**In Use**
Planeness of Sides	<0.001 in.	<0.002 in.	<0.025 mm	<0.05 mm
Distance Between Opposite Sides	2 in. ± 0.005 in.	2 in. ± 0.02 in.	50 mm ± 0.13 mm	50 mm ± 0.50 mm
Height of Each Compartment	2 in. ± 0.001 in. to -0.005 in	2 in. ± 0.01 in. to -0.015 in.	50 mm ± 0.25 mm to -0.013 mm	50 mm ± 0.25 mm to -0.38 mm
Angle Between Adjacent Faces[A]	90 ± 0.5°	90 ± 0.5°	90 ± 0.5°	90 ± 0.5°

Notes:

A Measured at points slightly removed from the intersection. Measured separately for each compartment between all the interior faces and the adjacent face and between interior faces and top and bottom planes of the mold.

Permissible Variations of Specimen Molds
Table 1

5.4 *Mixer, Bowl and Paddle*, an electrically driven mechanical mixer of the type equipped with paddle and mixing bowl, as specified in T 162.

5.5 *Flow Table and Flow Mold*, conforming to the requirements of M 152.

5.6 *Tamper,* a non-absorptive, nonabrasive, non-brittle material such as a rubber compound having a Shore A durometer hardness of 80 ± 10 or seasoned oak wood rendered non-absorptive by immersion for 15 min in paraffin at approximately 392°F or (200°C), shall have a cross section of about ½ by 1 in. or (13 by 25 mm) and a convenient length of about 5 to 6 in. or (120 to 150 mm). The tamping face shall be flat and at right angles to the length of the tamper.

5.7 *Trowel*, having a steel blade 4 to 6 in. (100 to 150 mm) in length, with straight edges.

5.8 *Moist Cabinet or Room,* conforming to the requirements of Specification M 201.

5.9 *Testing Machine*, either the hydraulic or the screw type, with sufficient opening between the upper bearing surface and the lower bearing surface of the machine to permit the use of verifying apparatus. The load applied to the test specimen shall be indicated with an accuracy of ± 1.0%. If the load applied by the compression machine is registered on a dial, the dial shall be provided with a graduated scale that can be read to at least the nearest 0.1% of the full scale load (Note 2). The dial shall be readable within 1% of the indicated load at any given load level within the loading range. In no case shall the loading range of a dial be considered to include loads below the value that is 100 times the smallest change of load that can be read on the scale. The scale shall be provided with a graduation line equal to zero and so numbered. The dial pointer shall be of sufficient length to reach the graduation marks; the width of the end of the pointer shall not exceed the clear distance between the smallest graduations. Each dial shall be equipped with a zero adjustment that is easily accessible from the outside of the dial case, and with a suitable device that at all times until reset, will indicate to within 1 percent accuracy the maximum load applied to the specimen.

5.9.1 If the testing machine load is indicated in digital form, the numerical display must be large enough to be easily read. The numerical increment must be equal to or less than 0.10 percent of the full scale load of a given loading range. In no case shall the verified loading range include loads less than the minimum numerical increment multiplied by 100. The accuracy of the indicated load must be within 1.0 percent for any value displayed within the verified loading range. Provision must be made for adjusting to indicate true zero at zero load. There shall be provided a maximum load indicator that at all times until reset will indicate within 1 percent system accuracy the maximum load applied to the specimen.

Note 2: As close as can be read is considered $^1/_{50}$ in. or (0.5 mm) along the arc described by the end of the pointer. Also, one half of the scale interval is about as close as can reasonably be read when the spacing on the load indicating mechanism is between $^1/_{25}$ in. or (1 mm) and $^1/_{16}$ in. or (1.6 mm). When the spacing is between $^1/_{16}$ in. or (1.6 mm) and ⅛ in. or (3.2 mm), one third of the scale interval can be read with reasonable certainty. When the spacing is ⅛ in. or (3.2 mm) or more, one fourth of the scale interval can be read with reasonable certainty.

5.9.2 The upper bearing shall be a spherically seated, hardened metal block firmly attached at the center of the upper head of the machine. The center of the sphere shall lie at the center of the surface of the block in contact with the specimen. The block shall be closely held in its spherical seat, but shall be free to tilt in any direction. A hardened metal bearing block shall be used beneath the specimen to minimize wear of the lower platen of the machine. To facilitate accurate centering of the test specimen in the compression machine, one of the two surfaces of the bearing blocks shall have a diameter or diagonal of between 70.7 mm [2.83 in.] (See Note 3) and 73.7 mm [2.9 in.]. When the upper block surface meets this requirement, the lower bearing surface shall be greater than 70.7 [2.83 in.]. When the lower block bearing surface meets this requirement, the diameter or diagonal of upper block bearing surface shall be between 70.7 and 79.4 [2.83 and 3⅛ in]. When the lower block is the only block with a diameter or diagonal between 70.7 and 73.7 mm [2.83 in and 2.9 in.], the lower block shall be used to center the test specimen. In that case, the lower block shall be centered with respect to the upper bearing block and held in position by suitable means. The bearing block surfaces intended for contact with the specimen shall have a Rockwell hardness number not less than 60 HRC. These surfaces shall not depart from plane surfaces by more than 0.013 mm [0.0005 in.] when the blocks are new and shall be maintained within a permissible variation of 0.025 mm [0.001 in.].

Note 3: The diagonal of 2-in. or (50-mm) cube is 2.83 in. (70.7 mm).

6. MATERIALS

6.1 *Graded Standard Sand:*

6.1.1 The sand (Note 4) used for making test specimens shall be natural silica sand conforming to the requirements for graded standard sand in ASTM C 778.

Note 4: *Segregation of Graded Sand* — The graded standard sand should be handled in such a manner as to prevent segregation, since variations in the grading of the sand cause variations in the consistency of the mortar. In emptying bins or sacks, care should be exercised to prevent the formation of mounds of sand or craters in the sand, down the slopes of which the coarser particles will roll. Bins should be of sufficient size to permit these precautions. Devices for drawing the sand from bins by gravity should not be used.

7. TEMPERATURE AND HUMIDITY

7.1 *Temperature* — The temperature of the air in the vicinity of the mixing slab, the dry materials, molds, base plates, and mixing bowl, shall be maintained between 68 and 81.5°F or (20 and 27.5°C). The temperature of the mixing water, moist closet or moist room, and water in the storage tank shall be set at 73.5°F or (23°C) and shall not vary from this temperature by more than ± 3°F or (± 1.7°C).

7.2 *Humidity* — The relative humidity of the laboratory shall be not less than 50 percent. The moist closet or moist room shall conform to the requirements of M 201.

8. TEST SPECIMENS

8.1 Make two or three specimens from a batch of mortar for each period of test or test age.

9. PREPARATION OF SPECIMEN MOLDS

9.1 Apply a thin coating of release agent to the interior faces of the mold and non-absorptive base plates. Apply oils and greases using an impregnated cloth or other suitable means. Wipe the mold faces and the base plate with a cloth as necessary to remove any excess release agent and to achieve a thin, even coating on the interior surfaces. When using an aerosol lubricant, spray the release agent directly onto the mold faces and base plate from a distance of 6 to 8 in. or (150 to 200 mm) to achieve complete coverage. After spraying, wipe the surface with a cloth as necessary to remove any excess aerosol lubricant. The residue coating should be just sufficient to allow a distinct fingerprint to remain following light finger pressure (Note 5).

9.2 Seal the surfaces where the halves of the mold join by applying a coating of light cup grease such as petrolatum. The amount should be sufficient to extrude slightly when the two halves are tightened together. Remove any excess grease with a cloth.

9.3 After placing the mold on its base plate (and attaching, if clamp-type) carefully remove with a dry cloth any excess oil or grease from the surface of the mold and the base plate to which watertight sealant is to be applied. As a sealant, use paraffin, microcrystalline wax, or a mixture of three parts paraffin to five parts rosin by mass. Liquefy the sealant by heating between 230 and 248°F or (110 and 120°C). Effect a watertight seal by applying the liquefied sealant at the outside contact lines between the mold and its base plate.

Note 5: Because aerosol lubricants evaporate, molds should be checked for a sufficient coating of lubricant immediately prior to use. If an extended period of time has elapsed since treatment, retreatment may be necessary.

Note 6: *Watertight Molds* — The mixture of paraffin and rosin specified for sealing the joints between molds and base plates may be found difficult to remove when molds are being cleaned. Use of straight paraffin is permissible if a watertight joint is secured, but due to the low strength of paraffin it should be used only when the mold is not held to the base plate by the paraffin alone. A watertight joint may be secured with paraffin alone by slightly warming the mold and base plate before brushing the joint. Molds so treated should be allowed to return to the specified temperature before use.

10. PROCEDURE

Note: **For Field fabrication of grout cubes, follow WSDOT Test Method 813.**

10.1 *Composition of Mortars*

10.1.1 The proportions of materials for the standard mortar shall be one part of cement to 2.75 parts of graded standard sand by mass. Use a water-cement ratio of 0.485 for all portland cements and 0.460 for all air-entraining portland cements. The amount of mixing water for other than portland and air-entraining portland cements shall be such as to produce a flow of 110 ± 5 as determined in accordance with Section 10.3 and shall be expressed as mass percent of cement.

10.1.2 The quantities of materials to be mixed at one time in the batch of mortar for making six and nine test specimens shall be as follows in Table 2:

	No. of Specimens	
	6	**9**
Cement, g	500	740
Sand, g	1375	2035
Water, mL: Portland (0.485)	242	359
Air-entraining portland (0.460)	230	340
Other (to flow of 110 ± 5)	—	—

Mixing Proportions for 2-in. Cubes
Table 2

10.2 *Preparation of Mortar:*

10.2.1 Mechanically mix in accordance with the procedure given in T 162.

10.3 *Determination of Flow:*

10.3.1 Carefully wipe the flow-table top clean and dry, and place the flow mold at the center. Place a layer of mortar about 1 in. or (25 mm) in thickness in the mold and tamp 20 times with the tamper. The tamping pressure shall be just sufficient to ensure uniform filling of the mold. Then fill the mold with mortar and tamp as specified for the first layer. Cut off the mortar to a plane surface, flush with the top of the mold, by drawing the straight edge of a trowel (held nearly perpendicular to the mold) with a sawing motion across the top of the mold. Wipe the table top clean and dry, being especially careful to remove any water from around the edge of the flow mold. Lift the mold away from the mortar 1 min after completing the mixing operation. Immediately, drop the table through a height of ½ in. or (13 mm) 25 times in 15 seconds. Using the calipers, determine the flow by measuring the diameters of the mortar along the lines scribed in the table top, adding the four readings. The total of the four readings from the calipers equals the percent increase of the original diameter of the mortar.

10.3.2 For portland and air-entraining portland cements, merely record the flow.

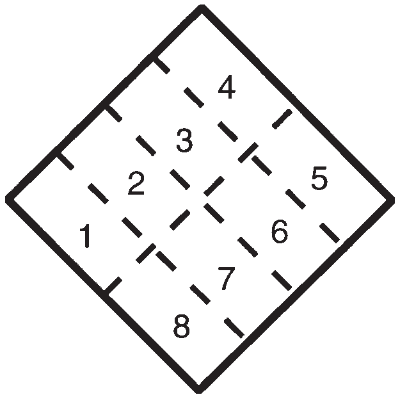
10.3.3 In the case of cements other than portland or air-entraining portland cements, make trial mortars with varying percentages of water until the specified flow is obtained. Make each trial with fresh mortar.

10.3.4 Immediately following completion of the flow test, return the mortar from the flow table to the mixing bowl. Quickly scrape the bowl sides and transfer into the batch the mortar that may have collected on the side of the bowl and then remix the entire batch 15 seconds at medium speed. Upon completion of mixing, the mixing paddle shall be shaken to remove excess mortar into the mixing bowl.

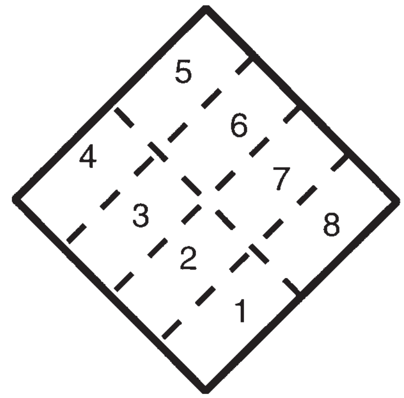
10.3.5 When a duplicate batch is to be made immediately for additional specimens, the flow test may be omitted and the mortar allowed to stand in the mixing bowl 90 seconds without covering. During the last 15 seconds of this interval, quickly scrape the bowl sides and transfer into the batch the mortar that may have collected on the side of the bowl. Then remix for 15 seconds at medium speed.

10.4 *Molding Test Specimens:*

10.4.1 Complete the consolidation of the mortar in the molds either by hand tamping or by a qualified alternative method. Alternative methods include but are not limited to the use of vibrating table or mechanical devices.



Rounds 1 and 3



Rounds 2 and 4

Order of Tamping in Molding of Test specimens
Figure 1

10.4.2 Hand Tamping-Start molding the specimens within a total elapsed time of not more than 2 min and 30 seconds after completion of the original mixing of the mortar batch. Place a layer of mortar about 1 in. or (25 mm) (approximately one half of the depth of the mold) in all of the cube compartments. Tamp the mortar in each cube compartment 32 times in about 10 seconds in 4 rounds, each round to be at right angles to the other and consisting of eight adjoining strokes over the surface of the specimen, as illustrated in Figure 1. The tamping pressure shall be just sufficient to ensure uniform filling of the molds. The 4 rounds of tamping (32 strokes) of the mortar shall be completed in one cube before going to the next. When the tamping of the first layer in all of the cube compartments is completed, fill the compartments with the remaining mortar and then tamp as specified for the first layer. During tamping of the second layer bring in the mortar forced out onto the tops of the molds after each round of tamping by means of the gloved fingers and the tamper upon completion of each round and before starting the next round of tamping. On completion of the tamping, the tops of all cubes should extend slightly above the tops of the molds. Bring in the mortar that has been forced out onto the tops of the molds with a trowel and smooth off the cubes by drawing the flat side of the trowel (with the leading edge slightly raised) once across the top of each cube at right angles to the length of the mold. Then, for the purpose of leveling the mortar and making the mortar that protrudes above the top of the mold of more uniform thickness, draw the flat side of the trowel (with the leading edge slightly raised) lightly once along the length of the mold. Cut off the mortar to a plane surface flush with the top of the mold by drawing the straight edge of the trowel (held nearly perpendicular to the mold) with a sawing motion over the length of the mold.

10.4.3 *Alternative Methods*—Any consolidation method may be used that meets the qualification requirements of this section. The consolidation method consists of a specific procedure, equipment and consolidation device, as selected and used in a consistent manner by a specific laboratory. The mortar batch size of the method may be modified to accommodate the apparatus, provided the proportions maintain the same ratios as given in Section 10.1.2.

10.4.3.1 Separate qualifications are required for the following classifications:

10.4.3.2 *Class A, Non-air Entrained Cements*—For use in concrete. Refer to M 85, M 240 and ASTM C 1157.

10.4.3.3 *Class B, Air-entrained Cements*—For use in concrete. Refer to M 85, M 240 and ASTM C 1157.

10.4.3.4 *Class C, Masonry, Mortar and Stucco Cements*—Refer to ASTM C 91, C 1328, and C 1329.

10.4.3.5 An alternative method may only be used to test the cement types as given in Section 10.4.3.1 above, for which it has been qualified.

10.4.3.6 It can also be used for Strength Activity Index determinations for fly ash and slag, refer to M 295 and M 302, provided the alternative method has qualified for both Class A and Class C cements.

10.4.4 *Qualification Procedure*—Contact CCRL to purchase cement samples that have been used in the Proficiency Sample Program (PSP). Four samples (5 kg each) of the class to be qualified will be required to complete a single qualification (See Note 7).

10.4.4.1 In one day, prepare replicate six-cube or nine-cube batches using one of the cements and cast a minimum of 36 cubes. Complete one round of tests on each cement on different days. Store and test all specimens as prescribed in the sections below. Test all cubes at the age of seven-days.

10.4.4.2 Tabulate the compressive strength data and complete the mathematical analyses as instructed in Annex A1.

10.4.5 *Re-qualification of the Alternate Compaction Method:*

10.4.5.1 Re-qualification of the method shall be required if any of the following occur:

- Evidence that the method may not be providing data in accordance with the requirements of Table 2.
- Results that differ from the reported final average of a CCRL-PSP sample with a rating of three or less.
- Results that differ from the accepted value of a known reference sample with established strength values by more than twice the multi-laboratory 1s percent values of Table 2. Before starting the re-qualification procedure, evaluate all

aspects of cube fabrication and testing process to determine if the offending result is due to some systematic error or just an occasional random event.

10.4.5.2 If the compaction equipment is replaced, significantly modified, repaired, or has been recalibrated, re-qualify the equipment in accordance with Section 10.4.4.

Note 7: It is recommended that a large homogenous sample of cement be prepared at the time of qualification for use as a secondary standard and for method evaluation. Frequent testing of this sample will give early warning of any changes in the performance of the apparatus.

10.5 *Storage of Test Specimens* — Immediately upon completion of molding, place the test specimens in the moist closet or moist room. Keep all test specimens, immediately after molding, in the molds on the base plates in the moist closet or moist room from 20 to 24 hrs with their upper surfaces exposed to the moist air but protected from dripping water. If the specimens are removed from the molds before 24 hrs, keep them on the shelves of the moist closet or moist room until they are 24 hrs old, and then immerse the specimens, except those for the 24-hr test, in saturated lime water in storage tanks constructed of non-corroding materials. Keep the storage water clean by changing as required.

10.6 *Determination of Compressive Strength*:

10.6.1 Test the specimens immediately after their removal from the moist closet in the case of 24 hrs specimens, and from storage water in the case of all other specimens. All test specimens for a given test age shall be broken within the permissible tolerance prescribed as follows in Table 3:

Test Age	Permissible Tolerance
24 hrs	± ½ hr
3 days	± 1 hr
7 days	± 3 hr
28 days	± 12 hr

Testing Time tolerances
Table 3

If more than one specimen at a time is removed from the moist closet for the 24-hr tests, keep these specimens covered with a damp cloth until time of testing. If more than one specimen at a time is removed from the storage water for testing, keep these specimens in water at a temperature of 73.4 ± 3°F or (23 ± 2°C) and of sufficient depth to completely immerse each specimen until time of testing.

10.6.2 Wipe each specimen to a surface-dry condition, and remove any loose sand grains or incrustations from the faces that will be in contact with the bearing blocks of the testing machine. Check these faces by applying a straightedge (Note 8). If there is appreciable curvature, grind the face or faces to plane surfaces or discard the specimen. A periodic check of the cross-sectional area of the specimens should be made.

Note 8: *Specimen Faces* — Results much lower than the true strength will be obtained by loading faces of the cube specimen that are not truly plane surfaces. Therefore, it is essential that specimen molds be kept scrupulously clean, as otherwise, large irregularities in the surfaces will occur. Instruments for cleaning molds should always be softer than the metal in the molds to prevent wear. In case grinding specimen faces is necessary, it can be accomplished best by rubbing the specimen on a sheet of fine emery paper or cloth glued to a plane surface, using only a moderate pressure. Such grinding is tedious for more than a few thousandths of an inch (hundredths of a millimeter); where more than this is found necessary, it is recommended that the specimen be discarded.

10.6.3 Apply the load to specimen faces that were in contact with the true plane surfaces of the mold. Carefully place the specimen in the testing machine below the center of the upper bearing block. Prior to the testing of each cube, it shall be ascertained that the spherically seated block is free to tilt. Use no cushioning or bedding materials. Bring the spherically seated block into uniform contact with the surface of the specimen. Apply the load rate at a relative rate of movement between the upper and lower platens corresponding to a loading on the specimen with the range of 200 to 400 lbs/s (900 to 1800 N/S). Obtain this designated rate of movement of the platen during the first half of the anticipated maximum load and make no adjustment in the rate of movement of the platen in the latter half of the loading especially while the cube is yielding before failure.

Note 9: It is advisable to apply only a very light coating of a good quality, light mineral oil to the spherical seat of the upper platen.

11. CALCULATION

11.1 Record the total maximum load indicated by the testing machine, and calculate the compressive strength as follows:

$$fm = \mathrm{P}/A \quad (1)$$

where:

fm = compressive strength in psi or (MPa),
P = total maximum load in lbf or (N), and
A = area of loaded surface in 2 or (mm 2).

Either 2-in. or (50-mm) cube specimens may be used for the determination of compressive strength, whether inch-pound or SI units are used. However, consistent units for load and area must be used to calculate strength in the units selected. If the cross-sectional area of a specimen varies more than 1.5 percent from the nominal, use the actual area for the calculation of the compressive strength. The compressive strength of all acceptable test specimens (see Section 12) made from the same sample and tested at the same period shall be averaged and reported to the nearest 10 psi (0.1 MPa).

12. REPORT

12.1 Report the flow to the nearest 1 percent and the water used to the nearest 0.1 percent. Average compressive strength of all specimens from the same sample shall be reported to the nearest 10 psi (0.1 MPa).

13. FAULTY SPECIMENS AND RETESTS

13.1 In determining the compressive strength, do not consider specimens that are manifestly faulty.

13.2 The maximum permissible range between specimens from the same mortar batch, at the same test age is 8.7 percent of the average when three cubes represent a test age and 7.6 percent when two cubes represent a test age (Note 10).

Note 10: The probability of exceeding these ranges is 1 in 100 when the within-batch coefficient of variation is 2.1 percent. The 2.1 percent is an average for laboratories participating in the portland cement and masonry cement reference sample programs of the Cement and Concrete Reference Laboratory.

13.3 If the range of three specimens exceeds the maximum in 13.2, discard the result which differs most from the average and check the range of the remaining two specimens. Make a retest of the sample if less than two specimens remain after discarding faulty specimens or discarding tests that fail to comply with the maximum permissible range of two specimens.

Note 11: Reliable strength results depend upon careful observance of all of the specified requirements and procedures. Erratic results at a given test period indicate that some of the requirements and procedures have not been carefully observed; for example, those covering the testing of the specimens as prescribed in 10.6.2 and 10.6.3. Improper centering of specimens resulting in oblique fractures or lateral movement of one of the heads of the testing machine during loading will cause lower strength results.

14. PRECISION AND BIAS

See AASHTO T 106-09 for Precision and Bias.

Performance Exam Checklist

Compressive Strength of Hydraulic Cement Mortar for AASHTO T 106

Participant Name ______________________________ Exam Date _______________

Procedure Element	**Yes**	**No**
1. The tester has a copy of the current procedure on hand?	❒	❒
2. All equipment is functioning according to the test procedure, and if required, has the current calibration/verification tags present?	❒	❒
3. Cubes are broken within permissible tolerance for time?	❒	❒
4. Cubes tested immediately after removal from moist closet?	❒	❒
5. Specimens covered with damp cloth while out of moist room closet?	❒	❒
6. Cubes wiped clean of sand, and wiped to surface dry condition prior to testing?	❒	❒
7. Faces to contact the bearing blocks are those that were in contact with the mold?	❒	❒
8. Faces that will contact the bearing blocks checked with a straightedge?	❒	❒
9. Cross-sectional area determined in respect to those faces contacting the bearing blocks?	❒	❒
10. Prior to testing each cube, the spherically seated block was checked for freedom to tilt?	❒	❒
11. Load rate of 200 to 400 lbf/s (900-1800 N/s) obtained during the first half of the anticipated load?	❒	❒
12. No adjustment in rate was made during the second half of the loading?	❒	❒
13. Compressive strength of cubes averaged and reported to the nearest 10 psi (0.1 MPa)?	❒	❒

First attempt: Pass ❒ Fail ❒ Second attempt: Pass ❒ Fail ❒

Signature of Examiner ____________________________________

Comments:

Performance Exam Checklist

AASHTO T 121M/T 121
Density (Unit Weight), Yield and Air Content (Gravimetric) of Concrete

Participant Name ______________________ Exam Date ______________

Procedure Element	Yes	No
1. The tester has a copy of the current procedure on hand?	❒	❒
2. All equipment is functioning according to the test procedure, and if required, has the current calibration/verification tags present?	❒	❒
3. Container dampened?	❒	❒
4. Freshly mixed concrete sampled in accordance with WAQTC TM 2?	❒	❒
5. Container filled in three equal layers, slightly overfilling the last layer?	❒	❒
6. Each layer rodded throughout its depth 25 times with hemispherical end of rod, uniformly distributing strokes?	❒	❒
7. Bottom layer rodded throughout its depth, without forcibly striking the bottom of the container?	❒	❒
8. Middle and top layers rodded, each throughout their depths and penetrating 1 in. (25 mm) into the underlying layer?	❒	❒
9. Sides of the container tapped 10 to 15 times with the mallet after rodding each layer?	❒	❒
10. Concrete struck off level with top of container using the strike off plate?	❒	❒
11. Clean all excess concrete from the exterior and determine the net mass of concrete to the nearest 0.1 lb.	❒	❒
12. All calculations performed correctly?	❒	❒

First attempt: Pass ❒ Fail ❒ Second attempt: Pass ❒ Fail ❒

Signature of Examiner ______________________________

Comments:

Washington State Department of Transportation

WSDOT Test Method T 125

Determination of Fiber Length Percentages in Wood Strand Mulch

1. SCOPE

   1.1. This test method covers the determination of the percentage, by mass, of fiber strands in a wood strand mulch sample meeting the specified requirements.

   1.2. This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. REFERENCED DOCUMENTS

   2.1. AASHTO Standards:
   - M 231, Weighing Devices Used in the Testing of Materials
   - T 248, Reducing Samples of Aggregate to Testing Size

3. SUMMARY OF TEST METHOD

   3.1. A sample of wood strand mulch is separated into individual fiber strands and the length, width and thickness of each strand is measured. The fiber stands are then separated into two categories; Strands meeting specified requirements and Strands not meeting specified requirements. The percentage of wood fiber strand is then computed and compared to the requirements of the specification. (See Calculation below)

4. APPARATUS

   4.1. *Balance* — shall have sufficient capacity, be readable to 0.1 percent of the sample mass, or better, and conform to the requirements of AASHTO M 231 for general-purpose balance required for the principle sample mass being tested.

   4.2 *Measuring device* — capable of reading to the nearest 1/16th inch (can either be one device or two separate devices)

5. SAMPLING

   5.1 Split a bale of wood strand mulch into three approximately equal sections. From the interior face of each section obtain a minimum of 150 g of fiber strand, taking care not to damage the material.

   5.2 Recombine the three 150 g samples and reduce the combined sample to a minimum sample size of 100g, in accordance with FOP for AASHTO T 248, Method B Quartering.

6. SAMPLE PREPARATION

6.1. Air dry the sample to a Constant Mass as defined in AASHTO T 265.

7. PROCEDURE

7.1. Spread the sample on a clean flat surface large enough to permit careful inspection of each strand. Measure the length, width and thickness of each strand in the 100g sample.

7.2. Compare the measurements of each strand to the specified requirements and separate the strands into two categories:

Strands meeting specified requirements

Strands not meeting specified requirements

7.3. Determine the total mass of each category.

8. CALCULATION

8.1. Report the following information:

8.1.1. Calculate the percentage of fiber strand meeting the specified requirements to the nearest one percent as follows:

$$P = [(S) / (S+N)] \times 100$$

where:

P = percent of strands meeting the required specifications
S = mass of strands meeting required specifications
N = mass of strands not meeting required specifications

Performance Exam Checklist

WSDOT Test Method 125

Participant Name ______________________ Exam Date ____________

Procedure Element	Yes	No
1. The tester has a copy of the current procedure on hand?	❒	❒
2. All equipment is functioning according to the test procedure, and if required, has the current calibration/verification tags present?	❒	❒
3. Sample reduced to correct size?	❒	❒
4. Sample dried and cooled, if necessary?	❒	❒
5. Sample properly measured?	❒	❒
6. Strands separated into "meeting specification" and "not meeting specifications" categories?	❒	❒
7. Dry mass of each category determined to nearest 0.1 g?	❒	❒
8. Calculation performed correctly?	❒	❒

First attempt: Pass ❒ Fail ❒ Second attempt: Pass ❒ Fail ❒

Signature of Examiner ______________________________

Comments:

WSDOT Test Method T 126

Determination of Fiber Length Percentages in Hydraulically-Applied Erosion Control Products

1. SCOPE

   1.1 This method covers the procedure for measuring the fiber length of a Hydraulically-applied Erosion Control Product (HECP).

   1.2 HECP is engineered and processed to specific length and width dimensions to facilitate the hydraulic application process. When the correct percentages of fiber lengths and widths exist within the HECP for hydraulic planting, the result will be a properly layered, interlocking mulch to hold seed and moisture.

   1.3 This standard does not purport to address the safety problems associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. (**Warning-** HECP's may be dusty, a dust mask is recommended when working with these products.

2. TERMINOLOGY

   2.1 Hydraulically applied - applied within a slurry, solution, or emulsion to the soil surface as a spray-on or dropped-on application through various means (e.g. nozzle, tower, aerially, etc.) formation of a compound by the combining of water with some other substance.

   2.2 Hydraulically-applied Erosion Control Product (HECP) - A manufactured, degradable, pre-packaged fibrous material that is mixed with water and hydraulically applied as slurry, solution, or emulsion to reduce soil erosion and assist in the establishment and growth of vegetation.

3. APPARATUS

   3.1 Balance – shall have sufficient capacity, readable to 0.1 percent of the sample mass, or better, and conform to the requirements of AASHTO M 231 for general-purpose balance required for the principle sample mass being tested.

   3.2 Sieves – Meeting the requirements of AASHTO M 92

   3.3 Mechanical sieve shaker – Meeting the requirements of AASHTO T 27

4. SAMPLE PREPARATION

   Obtain approximate 60 grams of material from a full, sealed bag or bale in the following manner:

   Divide the bag or bale into thirds; top, middle and bottom of bag or bale.

Extract approximately 20 grams of material from the center of each portion (or the inside face of each ⅓ of a bale) taking care not to damage the extracted material.

Recombine the three samples and reduce the sample, in accordance with AASHTO 248 Method B, to approximately 15 grams. Place the sample in a large container and gently separate the compressed fiber.

5. PROCEDURE

5.1 Select sieves with suitable openings to furnish data required by the specifications. Nest the sieves in order of decreasing size from top to bottom and place the sample, or a portion of the sample, on the top sieve.

5.2 Place sieves in mechanical shaker and shake for a 5 minutes.

5.3 Determine the individual or cumulative mass retained on each sieve and the pan to the nearest 0.1g

6. CALCULATIONS

Calculate the percentage of fiber retained on each of the sieves using the following formula:

Percent Retained:

$$CPR = \frac{CMR}{M} x\ 100$$

Where:
CPR = Cumulative Percent Retained
CMR= Cumulative Mass Retained
M = Total Sample mass

7. REPORT

Results shall be reported as follows:

- Cumulative mass retained on each sieve
- Cumulative percent retained on each sieve
- Percent passing and retained on each sieve shall be reported to the nearest 1 percent

WSDOT SOP 128

SAMPLING FOR AGGREGATE SOURCE APPROVAL

1. SCOPE

This method describes the procedure for sampling pits and quarries for Aggregate Source Approval (ASA).

2. SIGNIFICANCE AND USE

There are two methods for initiating the process for an Aggregate Source Approval:

a. The source owner request approval, pays for the sampling and testing, and coordinates this through the State Materials Laboratory who coordinates with the Regions. Sample is obtained by the Region Independent Assurance Inspector (IAI) or a delegate of the Region Materials Engineer.

b. The aggregate source is sampled and tested as part of a WSDOT project, in which case the WSDOT project pays for the sampling and testing costs which may or may not be coordinated with the ASA process at the State Materials Laboratory. Sample is obtained by the IAI or a delegate of the Region Materials Engineer.

3. SAFETY

All WSDOT employee required to sample from a pit or quarry will contact the pit/quarry owner or their designated representative prior to arrival at the site and arrange for an escort into the sampling site.

All WSDOT employees will be accompanied by the pit/quarry owner or their representative during the sampling process.

This standard does not purport to address all of the safety concerns, associated with its use. It is the responsibility of the user of this standard operating procedure to establish a pre-activity safety plan prior to use.

4. SAMPLING

All samples will be obtained in accordance with WSDOT FOP for AASHTO T 2.

Stockpiles produced for ASA sampling must contain a minimum of 10 tons of material. The material in the stockpile shall be of the same quality as the final product.

Sampling location and size of sample is listed in Table 1.

Aggregate Type	Sampling Site	Size of Sample in lbs	Notes
Concrete Coarse	Stockpile	50-100	Material must be clean and washed
Concrete Fine	Stockpile	30-40	Material must be clean and washed
Crushed Surfacing /Mineral Aggregate	Stockpile	80-100	For quality tests on crushed materials submit approximately 80 lbs of 1¼” minus material. Samples obtained for quarry spalls may not be used for quality tests for crushed materials.
Quarry Spalls	Face of pit , transport unit or stockpile	50-80	No rock larger than 4” in diameter.
All other Aggregate Types	Face of pit , transport unit or stockpile	50-80	No rock larger than 4” in diameter.

Table 1

6. REPORT

The Regional Materials Engineer’s (RME) representative will record the following information in an Inspector’s Daily Report (IDR) DOT form 422-004A EF:

- Name of Source Owner’s Representative accompanying the RME representative during sampling process.
- Time and Date of sampling
- Location where the sample is taken (stockpile/pit/face)
- Amount of sample (pounds and number of bags)
- Any concerns or specific request the Owner’s representative may have.

The RME's representative shall take pictures of the following items; a wide view of the mining operation, the sampling location in the pit or quarry, a close-up of the material in the stockpile being sampled (when applicable), and a close-up of the material sampled.

The IDR information and pictures will be e-mailed to the State ASA Engineer.

WSDOT FOP for AASHTO T 166[1]

Bulk Specific Gravity of Compacted Hot Mix Asphalt Using Saturated Surface-Dry Specimens

1. SCOPE

   1.1 This method of test covers the determination of bulk specific gravity of specimens of compacted hot mix asphalt.

   1.2 Definition:

   1.3 *Bulk specific gravity (of solids)*—the ratio of the mass in air of a unit volume of a permeable material (including both permeable and impermeable voids normal to the material) at a stated temperature to the weight in air of equal density of an equal volume of gas-free distilled water at a stated temperature. The form of the expression shall be:

   Bulk specific gravity x/y °C

   where:
   x = temperature of the material, and
   y = temperature of the water

   1.4 The bulk specific gravity of the compacted hot mix asphalt may be used in calculating the unit mass of the mixture.

   1.5 The values stated in English units are to be regarded as the standard.

   Note: Method A shall be used for laboratory compacted specimens, and field specimens compacted using gyratory compactor.

   Method C shall be used for asphalt pavement cores.

2. REFERENCED DOCUMENTS

   2.1 AASHTO Standards:
   - M 231, Weighing Devices Used in the Testing of Materials
   - T 275, Bulk Specific Gravity of Compacted Bituminous Mixtures Using Paraffin-Coated Specimens

[1] This Test Method is based on AASHTO T 166-07.

3. TEST SPECIMENS

3.1 Test specimens may be either laboratory-molded HMA mixtures or from HMA pavements. The mixtures may be surface, wearing, leveling or base course materials.

3.2 *Size of Specimens* — It is recommended that: (1) the diameter of cylindrically molded or cored specimens, or the length of the sides of sawed specimens, be at least equal to four times the maximum size of the aggregate; and (2) the thickness of specimens be at least one-and-one-half times the maximum size of the aggregate.

3.3 Specimens shall be taken from pavements with core drill, diamond or carborundum saw, or by other suitable means.

3.4 Care shall be taken to avoid distortion, bending, or cracking of specimens during and after the removal from pavement or mold. Specimens shall be stored in a safe, cool place.

3.5 Specimens shall be free from foreign materials such as seal coat, tack coat, foundation material, soil, paper, or foil.

3.6 If desired, specimens may be separated from other pavement layers by sawing or other suitable means. Care should be exercised to ensure sawing does not damage the specimens.

METHOD A

4. APPARATUS

4.1 *Weighing Device* — The weighing device shall have sufficient capacity, be readable to 0.1 percent of the specimen mass, or better, and conform to the requirements of AASHTO M 231. The weighing device shall be equipped with suitable suspension apparatus and holder to permit weighing the specimen while suspended from the center of scale pan of the weighing device.

4.2 *Suspension Apparatus* — The wire suspending the container shall be the smallest practical size to minimize any possible effects of a variable immersed length. The suspension apparatus shall be constructed to enable the container to be immersed to a depth sufficient to cover it and the specimen during weighing. Care should be exercised to ensure no trapped air bubbles exist under the specimen.

4.3 *Water Bath* — for immersing the specimen in water while suspended under the weighing device, equipped with an overflow outlet for maintaining a constant water level.

5. PROCEDURE

5.1 Dry the specimen to a constant mass (Note 1). Cool the specimen to room temperature for a minimum of 15 hours and a maximum of 24 hours at 77 ± 9°F (25 ± 5°C) per SOP 731 and record the dry mass as A. Immerse each specimen in water at 77 ± 1.8°F (25 ± 1°C) for 4 ± 1 minute and record the immersed mass as C. Remove the specimen from the water, damp dry the specimen by blotting with a damp towel as quickly as possible (blotting not to exceed 10s), and determine the surface-dry mass as, B. Any water that seeps from the specimen during the weighing operation is considered part of the saturated specimen (Note 1). Each specimen shall be immersed and weighed individually.

Note 1: Constant mass shall be defined as the mass at which further drying at 125 ± 5°F (52 ± 3°C) does not alter the mass by more than 0.1 percent. Specimen saturated with water shall initially be dried overnight at 125 ± 5°F (52 ± 3°C) and then weighed at 2-hour drying intervals. Recently molded laboratory specimens which have not been exposed to moisture do not require drying.

Note 2: If desired, the sequence of testing operations may be changed to expedite the test results. For example, first the immersed mass (C) can be taken, then the surface-dry mass (B), and finally the dry mass (A).

Note 3: Terry cloth has been found to work well for an absorbent cloth. Damp is considered to be when no water can be wrung from towel.

6. CALCULATION

6.1 Calculate the bulk specific gravity of the specimens as follows (round and report the value to the nearest three decimal places):

$$\text{Bulk Sp. Gr.} = \frac{A}{B - C}$$

where:

A = mass in grams of specimen in air,
B = mass in grams of surface-dry specimen in air,
C = mass in grams of specimen in water.

6.2 Calculate the percent water absorbed by the specimen (on volume basis) as follows:

$$\text{Percent Water Absorbed by Volume} = \frac{B - A}{B - C} \times 100$$

6.3 If the percent water absorbed by the specimen in Section 5.1 exceeds 2 percent, use T 275 (Bulk Specific Gravity of Compacted Bituminous Mixtures Using Paraffin-Coated Specimens) to determine the bulk specific gravity.

METHOD B

WSDOT does not use Method B and has removed this section from the procedure.

METHOD C (RAPID TEST)

10. PROCEDURE

10.1 This procedure can be used for testing specimens which are not required to be saved and which contain substantial amount of moisture. Specimens obtained by coring or sawing can be tested the same day by this method.

10.2 The testing procedure shall be the same as given in Sections 5 except for the sequence of operations. The dry mass (A) of the specimen is determined last as follows.

Note 4: A microwave oven can be used to speed up the process by initially heating the sample so that it can be broken into small pieces prior to placing it into the drying oven.

10.3 Place the specimen in a large flat bottom drying pan of known mass. Place the pan and specimen in a 325 ± 25º F (164 ± 14ºC) oven. Leave the specimen in the oven until it can be easily separated to the point where the particles of the fine aggregate-asphalt portion are not larger than ¼ in. (6.4 mm). Place the separated specimen in the 325º F (164ºC) oven and dry to a constant mass. The test sample shall be initially dried for a minimum of 90 minutes, and it's mass determined. Then, at 30 minute intervals until constant mass is achieved.

Note: If samples are placed in the oven overnight for a minimum of 6 hours at 230°F, then the 90 minute weighting is not necessary.

10.4 Cool the pan and specimen to room temperature at 77 ± 9°F (25 ± 5°C). Determine the mass of the pan and specimen, subtract the mass of the pan and record the dry mass of the pan and record the dry mass, A.

11. CALCULATIONS

11.1 Calculate the bulk specific gravity per Sections 6.1.

12. REPORT

12.1 The report shall include the following:

12.1.1 Bulk Specific Gravity reported to the nearest thousandth. (0.001)

12.1.2 Absorption reported to the nearest hundredth. (0.01)

13. PRECISION

13.1 Duplicate specific gravity results by the same operator should not be considered suspect unless they differ more than 0.02.

Performance Exam Checklist

WSDOT FOP for AASHTO T 166
Bulk Specific Gravity of Compacted Hot Mix Asphalt Using Saturated Surface Dry Specimens

Participant Name ______________________________ Exam Date _______________

Procedure Element	**Yes**	**No**
1. The tester has a copy of the current procedure on hand?	❒	❒
2. All equipment is functioning according to the test procedure, and if required, has the current calibration/verification tags present?	❒	❒
Method A (For use with laboratory compacted specimens.)		
1. Compacted specimen cooled to room temperature (refer to WSDOT SOP 731, Procedure #5g), 77 ± 9 F, and record the dry mass.	❒	❒
2. Immerse each specimen in water at 77 ± 1.8°F for 3 to 5 minutes and record the immersed mass to the nearest 0.1 gram?	❒	❒
3. Remove sample from water, surface dry with damp towel and weigh the specimen in air at 77 ± 9 F to the nearest 0.1 gram?	❒	❒
4. Calculated the bulk specific gravity of the specimens per Section 6.1?	❒	❒
Method C (For use with pavement cores and chunks.)		
1. Immerse specimen in water at 77 ± 1.8ºF for 3 to 5 minutes and record the immersed weight to the nearest 0.1 gram?	❒	❒
2. Remove sample from water, surface dry by blotting with damp towel and immediately weigh specimen in air at 77 ± 9 F to the nearest 0.1 gram?	❒	❒
3. Place specimen in container (noting the empty container weight), then into an oven set at 325 ± 25º F until sample can be broken into small pieces?	❒	❒
4. Return container to oven until it has reached a constant weight?	❒	❒
5. Remove container and sample from oven and allow to cool to room temperature, 77 ± 9 F?	❒	❒
6. Weigh pan with sample and record to nearest 0.1 gram, deducting known weight of pan to arrive at oven-dried sample weight?	❒	❒
7. Calculated the bulk specific gravity of the specimen per Section 6.1?	❒	❒

First attempt: Pass ❒ Fail ❒ Second attempt: Pass ❒ Fail ❒

Signature of Examiner ____________________________________

Comments:

WSDOT FOP for AASHTO T 209[1]

Theoretical Maximum Specific Gravity and Density of Hot-Mix Asphalt Paving Mixtures

1. SCOPE

   1.1 This test method covers the determination of the theoretical maximum specific gravity and density of uncompacted hot-mix asphalt paving mixtures at 77°F (25°C).

   1.2 The values stated in English units are to be regarded as the standard.

   1.3 This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. REFERENCED DOCUMENTS

   2.1 AASHTO Standards:
   - M 231, Weighing Devices Used in the Testing of Materials
   - PP 57, Establishing Requirements for and Performing Equipment Standardizations
   - Standardizations and Checks
   - R 47, Reducing Samples of Hot Mix Asphalt to Testing Size
   - T 168, Sampling Bituminous Paving Mixtures

   2.2 ASTM Standards:
   - D 4311, Practice for Determining Asphalt Volume Correction to a Base Temperature
   - C 670, Preparing Precision and Bias Statements for Test Methods for Construction Materials

   2.3 Other Standards:

T 168	WAQTC FOP for AASHTO for Sampling Bituminous Paving Mixtures
T 712	WSDOT Standard Method of Reducing Bituminous Paving Mixtures
SOP 729	In Place Density of Bituminous Mixes Using the Nuclear Moisture-Density Gauge FOP for WAQTC TM 8
SOP 730	Standard Operating Procedure for Correlation of Nuclear Gauge Determined Density with Asphalt Concrete Pavement Cores
SOP 731	Method for Determining Volumetric Properties of Asphalt Concrete Pavement Class Superpave
SOP 732	Standard Operating Procedure for Superpave Volumetric Design for Hot-Mix Asphalt (HMA)

[1] This FOP is based on AASHTO T 209 (<u>2009</u>) and has been modified per WSDOT standards. To view the redline modifications, contact WSDOT Quality Systems Manager at (360)709-5412.

3. TERMINOLOGY

3.1 Definitions:

3.1.1 Density, as determined by this test method—the mass of a cubic meter of the material at 77°F (25°C) in English units, or the mass of a cubic foot of the material at 77°F (25°C) in inch-pound units.

3.1.2 Residual pressure, as employed by this test method—the pressure in a vacuum vessel when vacuum is applied.

3.1.3 Specific gravity, as determined by this test method—the ratio of a given mass of material at 77°F (25°C) to the mass of an equal volume of water at the same temperature.

4. SUMMARY OF TEST METHOD

4.1 A weighed sample of HMA paving mixture in the loose condition is placed in a tared vacuum vessel. Sufficient water is added to completely submerge the sample. Vacuum is applied for 15 ± 2 min to gradually reduce the residual pressure in the vacuum vessel. At the end of the vacuum period, the vacuum is gradually released. The volume of the sample of paving mixture is obtained by (Section 9.5.2) filling the vacuum container level full of water and weighing in air. At the time of weighing the temperature is measured as well as the mass. From the mass and volume measurements, the specific gravity or density at 77°F (25°C) is calculated. If the temperature employed is different from 77°F (25°C), an appropriate correction is applied.

5. SIGNIFICANCE AND USE

5.1 The theoretical maximum specific gravities and densities of hot-mix asphalt paving mixtures are intrinsic properties whose values are influenced by the composition of the mixtures in terms of types and amounts of aggregates and asphalt binder materials.

5.1.1 These properties are used to calculate percent air voids in compacted HMA.

5.1.2 These properties provide target values for the compaction of HMA.

5.1.3 These properties are essential when calculating the amount of asphalt binder absorbed by the internal porosity of the individual aggregate particles in HMA.

6. APPARATUS

6.1 Follow the procedures for performing equipment standardizations, standardization, and checks found in PP 57.

6.2 Vacuum Container:

6.2.1 The vacuum containers described must be capable of withstanding the full vacuum applied, and each must be equipped with the fittings and other accessories required by the test procedure being employed. The opening in the container leading to the vacuum pump shall be covered by a piece of No. 200 (75-µm) mesh to minimize the loss of fine material.

6.2.2 The capacity of the vacuum container should be between 2000 and 10,000-mL and depends on the minimum sample size requirements given in Section 7.2. Avoid using a small sample in a large container.

6.2.3 *Vacuum Bowl*, either a metal or plastic bowl with a diameter of approximately 180 to 260 mm (7.1 to 10.2 in.) and a bowl height of at least 160 mm (6.3 in.) equipped with a transparent cover fitted with a rubber gasket and a connection for the vacuum line.

6.2.4 *Vacuum Flask for Weighing in Air Only*, a thick-walled volumetric glass flask and a rubber stopper with a connection for the vacuum line.

6.2.5 *Pycnometer for Weighing in Air Only*, a glass, metal or plastic pycnometer.

6.3 Balance, conforming to the requirements of AASHTO M 231, Class G 2. The balance shall be standardized at least every 12 months.

6.3.1 For the mass determination-in-water method (Section 9.5.1), the balance shall be equipped with a suitable apparatus and holder to permit determining the mass of the sample while suspended below the balance. The wire suspending the holder shall be the smallest practical size to minimize any possible effects of a variable immersed length.

6.4 Vacuum pump or water aspirator, capable of evacuating air from the vacuum container to a residual pressure of 30 mm Hg (4.0 kPa) or less.

6.4.1 When a vacuum pump is used, a suitable trap of one or more filter flasks, or equivalent, shall be installed between the vacuum vessel and vacuum source to reduce the amount of water vapor entering the vacuum pump.

6.5 Absolute pressure gauge or vacuum gauge, used for annual standardization and traceable to NIST (mandatory) to be connected directly to the vacuum vessel and to be capable of measuring residual pressure down to 30 mm Hg (4.0 kPa), or less (preferably to zero). It is to be connected at the end of the vacuum line using an appropriate tube and either a “T” connector on the top of the vessel or by using a separate opening (from the vacuum line) in the top of the vessel to attach the hose.

Note 2: A residual pressure of 30 mm Hg (4.0 kPa) absolute pressure is approximately equivalent to 730 mm Hg (97 kPa) reading on vacuum gauge at sea level.

6.6 Thermometric Device (Mass Determination in Air), liquid-in-glass thermometers or other suitable thermometric device, accurate to 1ºF (0.5º C). The thermometric device shall be standardized at the test temperature at least every 12 months.

6.7 Water Bath, a water bath that can be maintained at a constant temperature between 73 and 82.9°F (22.8 and 28.3°C).

6.8 Bleeder Valve, attached to the vacuum train to facilitate adjustment of the vacuum being applied to the vacuum vessel.

6.9 Protective Gloves, used when handling glass equipment under vacuum.

6.10 Mallet, with a rubber or rawhide head.

7. SAMPLING

7.1 Obtain the sample in accordance with WAQTC FOP for AASHTO T 168 and WSDOT T 712.

7.2 The size of the sample shall conform to the requirements in Table 1. Samples larger than the capacity of the container may be tested a portion at a time.

Nominal Maximum Aggregate Size, mm	Minimum Sample Size, g
37.5 or greater	4000
19 to 25	2500
12.5 or smaller	1500

Minimum Sample Sizes
Table 1

8. STANDARDIZATION OF FLASKS, BOWLS, AND PYCNOMETERS

This section has been deleted by WSDOT and replaced with the following:

The volumetric flask or metal vacuum pycnometer will be standardized periodically in conformance with established verification procedures or per AASHTO T 209. Standardization shall be done at 77°F.

9. PROCEDURE

9.1 Separate the particles of the HMA sample by hand, taking care to avoid fracturing the aggregate, so that the particles of the fine aggregate portion are not larger than ¼ in (6.3 mm). If an HMA sample is not sufficiently soft to be separated manually, place it in a flat pan, and warm it in an oven until it can be separated as described.

9.2 WSDOT has deleted this section

9.3 Cool the sample to room temperature, and place it in a tared and standardized flask, bowl, or pycnometer. Weigh and designate the net mass of the sample as A. Add sufficient water at a temperature of approximately 25°C (77°F) to cover the sample completely.

9.4 Remove air trapped in the sample by applying gradually increased vacuum until the absolute pressure gauge or vacuum gauge reads 30 mm HG or less (3.7 ± 0.3 kPa or less). Maintain this residual pressure for 15 ± 2 min. Agitate the container and contents during the vacuum period either continuously by a mechanical device, or manually by vigorous shaking at intervals of about 2 minutes. Glass vessels should be shaken on a resilient surface such as a rubber or plastic mat, and not on a hard surface, so as to avoid excessive impact while under vacuum. To aid in releasing the trapped air from the metal vacuum pycnometer, tap the sides of the metal vacuum pycnometer 3 to 5 times with the mallet at approximately two minutes intervals.

The release of entrapped air may be facilitated by the addition of a few drops of suitable wetting agent .

9.5 At the end of the vacuum period, release the vacuum within 10 to 15 seconds. Start the 9 to 11 minute time, as described in 9.5.2, immediately upon starting the release of vacuum. Proceed to 9.5.2.

9.5.1 WSDOT has deleted this section

9.5.2 Weighing in Air—Fill the flask with water and adjust the contents to a temperature of 77 ± 2°F (25 ± 1°C) in a constant temperature water bath. Determine the mass of the container (and contents), completely filled, 9 to 11 minutes after starting Section 9.5. Designate this mass as **E**. Accurate filling may be ensured by the use of a glass cover plate.

In lieu of a constant temperature water bath described in 9.5.2, determine the temperature of the water within the flask or metal vacuum pycnometer and determine the appropriate density correction factor “R” using Table 2.

10. CALCULATION

10.1 Calculate the theoretical maximum specific gravity of the sample at 77°F (25°C) as follows:

10.1.1 Weighing in Air:

$$\text{Theoretical Maximum Specific Gravity} = \frac{A}{A + D - E}$$

where:

A = mass of oven-dry sample in air, g;

D = mass of container filled with water at 77°F (25°C), g; and

E = mass of container filled with sample and water at 77°F (25°C), g.

10.1.1.1 If the test temperature differs significantly from 77°F (25°C), correct for thermal effects as follows:

WSDOT has removed the AASHTO calculation and replaced it with the following calculations:

1. Determination using temperature correction:

$$\text{Theoretical Maximum Gravity} = \frac{A}{A + D - E} \times R$$

where:

A = mass of oven-dry sample in air, g;
D = mass of container filled with water at 77°F (25°C), g; and
E = mass of container filled with sample and water at 77°F (25°C), g.
R = Factor from Table 2 to correct density of water from the test temperature to 77°F (25°C).

Note: The flask standardization is done at 77 ± 0.4°F (25 ± 0.2°C).

2. Determination using weighted average:

$$\text{Weighted Average Maximum Specific Gravity} = \frac{(Sp.\ G_1 \times A_1) + (Sp.\ G_2 \times A_2)}{(A_1 + A_2)}$$

where:

$Sp.G_1$ = Specific gravity of first test segment
$Sp.G_2$ = Specific gravity of second test segment
A_1 and A_2 = Mass of dry sample in air of respective test segments

3. Calculate the rice density (calculate to one decimal place):

Rice density = Rice sp. gr. x 62.24 lb/ft.3 (997 kg/m^3)

C°	F°	"R"
22.8	73.0	1.00054
23.0	73.4	1.00050
23.2	73.8	1.00045
23.3	73.9	1.00042
23.4	74.1	1.00040
23.6	74.5	1.00035
23.8	74.8	1.00030
23.9	75.0	1.00028
24.0	75.2	1.00025
24.2	75.6	1.00020
24.4	75.9	1.00015
24.6	76.3	1.00010
24.8	76.6	1.00005
25.0	77.0	1.00000
25.2	77.4	0.99995
25.4	77.7	0.99990
25.6	78.1	0.99984
25.8	78.4	0.99979
26.0	78.8	0.99974
26.1	79.0	0.99971
26.2	79.2	0.99968
26.4	79.5	0.99963
26.6	79.9	0.99958
26.7	80.1	0.99955
27.2	81.0	0.99941
27.3	81.1	0.99938
27.8	82.0	0.99924
28.3	82.9	0.99910

Density Correction Factor "R"
Table 2

10.2 Theoretical maximum density at 77°F (25°C):

10.2.1 Calculate the corresponding theoretical maximum density at 77°F (25°C) as follows:

Theoretical maximum density at 77°F (25°C) = theoretical maximum specific gravity × 997.1 kg/m3 in SI units, or

Theoretical maximum density at 77°F (25°C) = theoretical maximum specific gravity × 62.245 lb/ft3 in inch-pound units.

where:

The specific gravity of water at 77°F (25°C) = 997.1 in SI units or = 62.245in inch-pound units.

11. SUPPLEMENTAL PROCEDURE FOR MIXTURES CONTAINING POROUS AGGREGATE

WSDOT has removed this section.

12. REPORT

12.1 Report the following information:

12.1.1 Specific gravity and density of the mixture to the third decimal place

12.1.2 Type of mixture,

12.1.3 Size of sample,

12.1.4 Number of samples,

12.1.5 Type of container, and

12.1.6 Type of procedure.

13. PRECISION

See AASHTO T-209 for Precision.

APPENDIX

Nonmandatory Information

A1. THEORETICAL MAXIMUM SPECIFIC GRAVITY FOR A LOOSE-PAVING MIXTURE

WSDOT has removed this section.

Performance Exam Checklist

Theoretical Maximum Specific Gravity and Density of HOT MIX ASPHALT Paving Mixtures FOP for AASHTO T 209

Participant Name ______________________ Exam Date ____________

Procedure Element	Yes	No
1. The tester has a copy of the current procedure on hand?	❒	❒
2. All equipment is functioning according to the test procedure, and if required, has the current standardization/verification tags present?	❒	❒
3. Particles of sample separated?	❒	❒
4. Care used not to fracture mineral fragments?	❒	❒
5. After separation, fine HMA particles not larger than ¼ inch?	❒	❒
6. Sample at room temperature?	❒	❒
7. Mass of bowl or flask determined?	❒	❒
8. Mass of sample and bowl or flask determined?	❒	❒
9. Mass of sample determined?	❒	❒
10. Water at approximately 77°F (25°C) added to cover sample?	❒	❒
11. Entrapped air removed using partial vacuum for 15 ± 2 min?	❒	❒
12. Container and contents agitated continuously by mechanical device or manually by vigorous shaking at intervals of about 2 minutes?	❒	❒
13. For metal pycnometer, strike 3 to 5 times with a mallet?	❒	❒
14. Release of entrapped air facilitated by addition of suitable wetting agent (optional)?	❒	❒
15. Flask determination:		
a. Flask filled with water?	❒	❒
1. Flask then placed in constant temperature water bath (optional) or?	❒	❒
2. Temperature of water in flask determined upon completion of 15d.?	❒	❒
b. Contents at 77 ± 2°F or density of water corrected using Table 2 in FOP?	❒	❒
c. Mass of filled flask determined 9 to 11 minutes after removal of entrapped air completed?	❒	❒
16. All calculations performed correctly?	❒	❒

First attempt: Pass ❒ Fail ❒ Second attempt: Pass ❒ Fail ❒

Signature of Examiner ______________________________

Comments:

WSDOT FOP for AASHTO T 248[1]

Reducing Samples of Aggregate to Testing Size

1. Scope

    1.1 This methods covers for the reduction of large samples of aggregate to the appropriate size for testing employing techniques that are intended to minimize variations in measured characteristics between the test samples so selected and the large sample.

    1.2 The values stated in English units are to be regarded as the standard.

    1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

    2.1 AASHTO Standards:

    T 2 Sampling of Aggregate
    T 84 Specific Gravity and Absorption of Coarse Aggregate

    2.2 ASTM Standards:

    C 125 Terminology Relating to Concrete and Concrete Aggregates

3. Terminology

    3.1 *Definitions* — The terms used in this practice are defined in ASTM C 125.

4. Significance and Use

    4.1 Specifications for aggregates require sampling portions of the material for testing. Other factors being equal, larger samples will tend to be more representative of the total supply. These methods provides for reducing the large sample obtained in the field or produced in the laboratory to a convenient size for conducting a number of tests to describe the material and measure its quality in a manner that the smaller test sample portion is most likely to be a representation of the larger sample, and thus of the total supply. The individual test methods provide for minimum amount of material to be tested.

[1] This FOP is based on AASHTO T 248-02.

4.2 Under certain circumstances, reduction in size of the large sample prior to testing is not recommended. Substantial differences between the selected test samples sometimes cannot be avoided, as for example, in the case of an aggregate having relatively few large size particles in the sample. The laws of chance dictate that these few particles may be unequally distributed among the reduced size test samples. Similarly, if the test sample is being examined for certain contaminants occurring as a few discrete fragments in only small percentages, caution should be used in interpreting results from the reduced size test sample. Chance inclusion or exclusion of only one or two particles in the selected test sample may importantly influence interpretation of the characteristics of the original sample. In these cases, the entire original sample should be tested.

4.3 Failure to carefully follow the procedures in this practice could result in providing a nonrepresentative sample to be used in subsequent testing

5. SELECTION OF METHOD

5.1 Fine Aggregate — Samples of fine aggregate that are ~~drier than the drier~~ saturated-surface-dry condition or drier (Note 1) may be reduced using a mechanical splitter according to Method A. Samples having free moisture on the particle surfaces may be reduced in size by quartering according to Method B, or by treating as a miniature stockpile as described in Method C.

5.1.1 If the use of Method B or Method C is desired, and the sample does not have free moisture on the particle surfaces, the sample may be moistened to achieve this condition, thoroughly mixed, and then the sample reduction performed.

Note 1: The method of determining the saturated-surface-dry condition is described in Test Method T 84. As a quick approximation, if the fine aggregate will retain its shape when molded in the hand, it may be considered to be wetter than saturated-surface-dry.

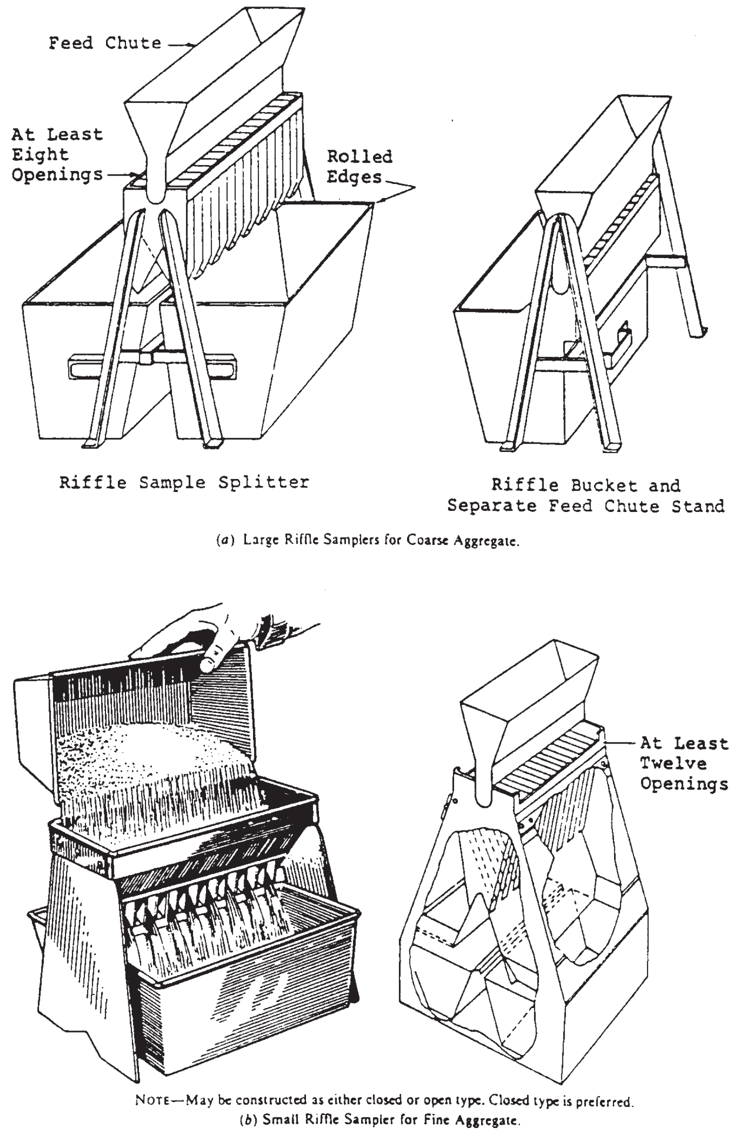
5.1.2 If use of Method A is desired and the sample has free moisture on the particle surfaces, the entire sample may be dried to at least the saturated-surface-dry condition, using temperatures that do not exceed those specified for any of the tests contemplated, and then the sample reduction performed. Alternatively, if the moist sample is very large, a preliminary split may be made using a mechanical splitter having wide chute openings of 1½ in. (38 mm) or more to reduce the sample to not less than 5000 g. The portion so obtained is then dried, and reduction to test sample size is completed using Method A.

5.2 Coarse Aggregates and Mixtures of Coarse and Fine Aggregates — Reduce the sample using a mechanical splitter in accordance with Method A (preferred method) or by quartering in accordance with Method B. The miniature stockpile Method C is not permitted for coarse aggregates or mixtures of coarse and fine aggregates.

5.3 Untreated materials shall be prepared for testing using this procedure. Treated materials (i.e., Hot Mix Asphalt or Asphalt Treated Base) shall be prepared for testing using WSDOT Test Method No. T 12 for reduction of size of samples of Asphalt treated materials.

6. SAMPLING

6.1 The samples of aggregate obtained in the field shall be taken in accordance with T 2, or as required by individual test methods. When tests for sieve analysis only are contemplated, the size of field sample listed in T 2 is usually adequate. When additional tests are to be conducted, the user shall determine that the initial size of the field sample is adequate to accomplish all intended tests. Similar procedures shall be used for aggregate production in the laboratory.



(*a*) Large Riffle Samplers for Coarse Aggregate.

NOTE—May be constructed as either closed or open type. Closed type is preferred.
(*b*) Small Riffle Sampler for Fine Aggregate.

Sample Dividers (Riffles)
Figure 1

Method A — Mechanical Splitter

7. APPARATUS

7.1 Sample Splitter — Sample splitters shall have an even number of equal width chutes, but not less than a total of eight for coarse aggregate, or 12 for fine aggregate, which discharge alternately to each side of the splitter, For coarse aggregate and mixed aggregate, the minimum width of the individual chutes shall be approximately 50 percent larger than the largest particles in the sample to be split (Note 2). For dry fine aggregate in which the entire sample will pass the ⅜ in. (9.5 mm) sieve, the minimum width of the individual chutes shall be at least 50 percent larger than the largest particles in the sample and the maximum width shall be ¾ in. (19 mm). The splitter shall be equipped with two receptacles to hold the two-halves of the sample following splitting. It shall also be equipped with a hopper or straight edge pan which has a width equal to or slightly less than the overall width of the assembly of chutes, by which the sample may be fed at a controlled rate to the chutes. The splitter and accessory equipment shall be so designed that the sample will flow smoothly without restriction or loss of material (Figure 1).

~~***Note 2:*** Mechanical splitters are commonly available in sizes adequate for coarse aggregate having the largest particle not over 1½ in. (37.5 mm).~~

8. PROCEDURE

8.1 Place the original sample in the hopper or pan and uniformly distribute it from edge to edge, so that when it is introduced into the chutes, approximately equal amounts will flow through each chute. The rate at which the sample is introduced shall be such as to allow free flowing through the chutes into the receptacles below. Reintroduce the portion of the sample in one of the receptacles into the splitter as many times as necessary to reduce the sample to the size specified for the intended test. The portion of the material collected in the other receptacle may be reserved for reduction in size for other tests.

Method B — Quartering

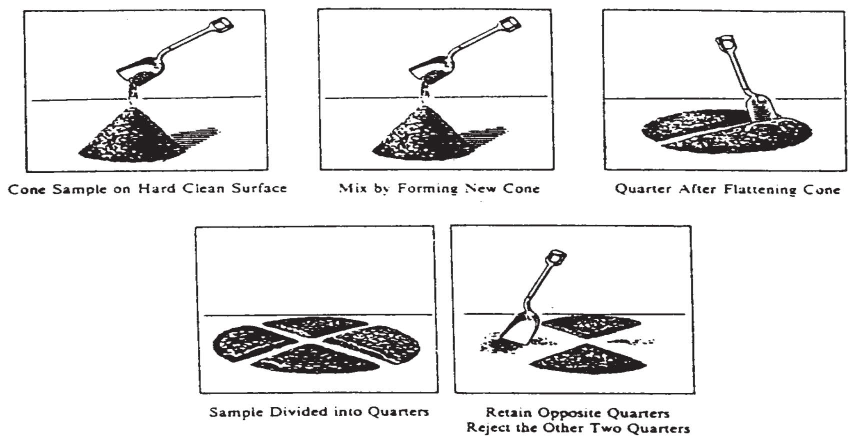
9. APPARATUS

9.1 Apparatus shall consist of a straightedge, scoop, shovel, or trowel; a broom or brush; and a canvas blanket approximately 6 by 8 ft. (2 by 2.5 m).

10. PROCEDURE

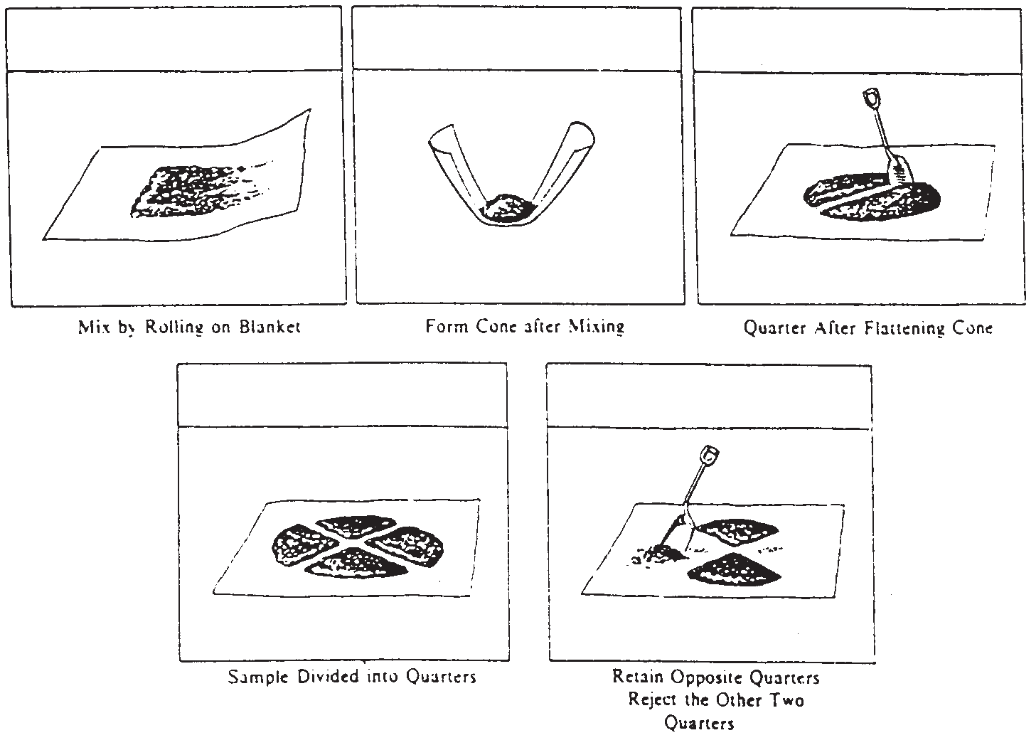
10.1 Use either the procedure described in 10.1.1 or 10.1.2 or a combination of both.

10.1.1 Place the original sample on a hard clean, level surface where there will be neither loss of material nor the accidental addition of foreign material. Mix the material thoroughly by turning the entire sample over three times. With the last turning, shovel the entire sample into a conical pile by depositing each shovelful on top of the preceding one. Carefully flatten the conical pile to a uniform thickness and diameter by pressing down the apex with a shovel so that each quarter sector of the resulting pile will contain the material originally in it. The diameter should be approximately four to eight times the thickness. Divide the flattened mass into four equal quarters with a shovel or trowel and remove two diagonally opposite quarters, including all fine material, and brush the cleared spaces clean. Successively mix and quarter the remaining material until the sample is reduced to the desired size (Figure 2).



Quartering on a Hard, Clean Level Surface
Figure 2

10.1.2 As an alternative to the procedure in 10.1.1 when the floor surface is uneven, the field sample may be placed on a canvas blanket and mixed with a shovel as described in 10.1.1, or by alternatively lifting each corner of the canvas and pulling it over the sample toward the diagonally opposite corner causing the material to be rolled. Flatten the pile as described in 10.1.1. Divide the sample as described in 10.1.1 or if the surface beneath the blanket is uneven, insert a stick or pipe beneath the blanket and under the center of the pile, then lift both ends of the stick, dividing the sample into two equal parts. Remove the stick leaving a fold of the blanket between the divided portions. Insert the stick under the center of the pile at right angles to the first division and again lift both ends of the stick, dividing the sample into four equal parts. Remove two diagonally opposite quarters, being careful to clean the fines from the blanket. Successively mix and quarter the remaining material until the sample is reduced to the desired size (Figure 3).



Quartering on a Canvas Blanket
Figure 3

Method C — Miniature Stockpile Sampling (Damp Fine Aggregate Only)

11. APPARATUS

11.1 Apparatus shall consist of a straight-edged scoop, shovel, or trowel for mixing the aggregate, and either a small sampling thief, small scoop, or spoon for sampling.

12. PROCEDURE

12.1 Place the original sample of damp fine aggregate on a hard clean, level surface where there will be neither loss of material nor the accidental addition of foreign material. Mix the material thoroughly by turning the entire sample over three times. With the last turning, shovel the entire sample into a conical pile by depositing each shovelful on top of the preceding one. If desired, the conical pile may be flattened to a uniform thickness and diameter by pressing the apex with a shovel so that each quarter sector of the resulting pile will contain the material originally in it. Obtain a sample for each test by selecting at least five increments of material at random locations from the miniature stockpile, using any of the sampling devices described in 11.1.

Performance Exam Checklist

Reducing Samples of Aggregates to Testing Size
FOP for AASHTO T 248

Participant Name ______________________________ Exam Date ______________

Procedure Element

	Yes	No
Preparation		
1. The tester has a copy of the current procedure on hand?	❒	❒
Selection of Method		
1. Fine Aggregate		
a. Saturated surface dry or drier: Method A (Splitter) used?	❒	❒
b. Free moisture present: Method B (Quartering) used?	❒	❒
2. Coarse Aggregate and Mixtures of Fine and Coarse Aggregates		
a. Method A used (preferred)?	❒	❒
b. Method B used?	❒	❒
Method A — Splitting		
1. Material spread uniformly on feeder?	❒	❒
2. Rate of feed slow enough so that sample flows freely through chutes?	❒	❒
3. Material in one pan re-split until desired mass is obtained?	❒	❒
4. Chutes are set correctly for material being split?	❒	❒
Method B — Quartering		
1. Sample placed on clean, hard, and level surface?	❒	❒
2. Mixed by turning over 3 times with shovel or by raising canvas and pulling over pile?	❒	❒
3. Conical pile formed?	❒	❒
4. Diameter equal to about 4 to 8 times thickness?	❒	❒
5. Pile flattened to uniform thickness and diameter?	❒	❒
6. Divided into 4 equal portions with shovel or trowel?	❒	❒
7. Two diagonally opposite quarters, including all fine material, removed?	❒	❒
8. Cleared space between quarters brushed clean?	❒	❒
9. Process continued until desired sample size is obtained when two opposite quarters combined?	❒	❒

The sample may be placed upon a blanket and a stick or pipe may be placed under the blanket to divide the pile into quarters.

First attempt: Pass ❒ Fail ❒ Second attempt: Pass ❒ Fail ❒

Signature of Examiner ______________________________

Comments:

WSDOT FOP for AASHTO T 335[1]

Determining the Percentage of Fracture in Coarse Aggregate

1. SCOPE

1.1. This test method covers the determination of the percentage, by mass, of a coarse aggregate sample that consists of fractured particles meeting specified requirements.

1.2. This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

1.3. The text of the standard reference notes provide explanatory material. These notes (excluding those in tables and figures) shall not be considered as requirements of the standard.

1.4 Method 1 will be used by WSDOT for determining the fracture of aggregate as required by the Standard Specifications.

2. REFERENCED DOCUMENTS

2.1. *AASHTO Standards:*

- M 92, Wire-Cloth Sieves for Testing Purposes
- M 231, Weighing Devices Used in the Testing of Materials

WSDOT Test Procedures:

- FOP for AASHTO T 2, Sampling of Aggregates
- FOP for WAQTC/AASHTO T 27/11, Sieve Analysis of Fine and Coarse Aggregates
- FOP for AASHTO T 248, Reducing Samples of Aggregate to Testing Size
- FOP for AASHTO T 255, Total Evaporable Moisture Content of Aggregate by Drying

3. SUMMARY OF TEST METHOD

3.1. A sample of aggregate is separated using the designated size of screen conforming to the specification controlling the determination of coarse and fine aggregate. The coarse aggregate particles are visually evaluated to determine their conformance to the defined fracture. The percentage of conforming particles, by mass, is determined for comparison to standard specifications.

4. APPARATUS

4.1. *Balance* — shall have sufficient capacity, be readable to 0.1 percent of the sample mass, or better, and conform to the requirements of M 231 for general-purpose balance required for the principle sample mass being tested.

4.2. *Sieves*—Meeting the requirements of M 92.

4.3. *Splitter*—Meeting the requirements of T 248.

[1] This FOP is based on AASHTO T 335-09 and has been modified per WSDOT standards. To view the redline modifications, contact WSDOT Quality Systems Manager at (360) 709-5412.

5. TERMINOLOGY

5.1. *fractured face*—an angular, rough, or broken surface of an aggregate particle created by crushing, or by other means. A face is considered a "fractured face" whenever one-half or more of the projected area, when viewed normal to that face, is fractured with sharp and well-defined edges (this excludes small nicks).

5.2. *fractured particle*—a particle of aggregate having at least the minimum number of fractured faces specified.

6. SAMPLING

Sample the aggregate in accordance with WSDOT FOP for AASHTO T 2 and reduce the sample in accordance with WSDOT FOP for AASHTO T 248, to the sample sizes shown in Table 2 of WSDOT FOP for AASHTO T 27/11.

7. SAMPLE PREPARATION

7.1. Where the specifications list only a total fracture percentage, the sample shall be prepared in accordance with Method 1.

7.2. *Method 1*—Combined Fracture Determination

7.2.1. Dry the sample sufficiently to obtain a clean separation of fine and coarse material in the sieving operation. Sieve the sample in accordance with WSDOT FOP for WAQTC/AASHTO T 27/11 over the No. 4 (4.75-mm) sieve.

Note 1: Where necessary, wash the sample over the sieve or sieves designated for the determination of fractured particles to remove any remaining fine material, and dry to a constant mass in accordance with WSDOT FOP for AASHTO T 255.

7.2.2. Reduce the sample using a splitter in accordance with WSDOT FOP for AASHTO T 248 to the appropriate size for test.

Nominal Maximum Particle Size	Minimum Sample Mass Retained No. 4 (4.75-mm) Sieve
1½ in (37.5 mm)	6 lb (2500 g)
1 in (25 mm)	3.5 lb (1500 g)
¾ in (19.0 mm)	2.5 lb (1000 g)
⅝ in. (16.0 mm)	2.0 lb (800 g)
½ in (12.5 mm)	1.5 lb (700 g)
⅜ in (9.5 mm)	0.9 lb (400 g)
No. 4 (4.75 mm)	0.4 lb (200 g)

* For aggregate, the nominal maximum size, (NMS) is the largest standard sieve opening listed in the applicable specification, upon which any material is permitted to be retained. For concrete aggregate, NMS is the smallest standard sieve opening through which the entire amount of aggregate is permitted to pass.

Note: For an aggregate specification having a generally unrestrictive gradation (i. e. wide range of permissible upper sizes), where the source consistently fully passes a screen substantially smaller than the maximum specified size, the nominal maximum size, for the purpose of defining sampling and test specimen size requirements may be adjusted to the screen, found by experience to retain no more than 5% of the materials.

Sample Size (Method 1, Combined Sieve Fracture)
Table 1

7.3 *Method 2*—Individual Sieve Fracture Determination WSDOT has deleted this section

8. PROCEDURE

8.1. Spread the sample on a clean flat surface large enough to permit careful inspection of each particle. To verify that a particle meets the fracture criteria, hold the aggregate particle so that the face is viewed directly. (See Section 5.1.)

8.2. To aid in making the fracture determination separate the sample into three categories: (1) fractured particles meeting the above criteria, (2) particles not meeting specification criteria, and (3) questionable or borderline particles.

8.3. Determine the mass of particles in the fractured category, the mass of questionable particles, and the mass of the unfractured particles.

9. CALCULATION

9.1. *Report the following information:*

9.1.1. Calculate the mass percentage of fracture faces to the nearest 1 percent as follows:

$$P = [(F + Q/2) / (F + Q + N)] \times 100$$

where:

P = percent of fracture,
F = mass of fractured particles,
Q = mass of questionable or borderline particles, and
N = mass of unfractured particles.

10. REPORT

Results shall be reported on standard forms approved for use by the agency. Report fracture to the nearest 1 percent.

Report the results using WSDOT Form 350-161 EF, 422-020X, or other report approved by the State Materials Engineer.

11. PRECISION AND BIAS

See AASHTO T 335 for precision and bias statements.

Performance Exam Checklist

Determining the Percentage of Fracture In Coarse Aggregate
WSDOT FOP for AASHTO T 335

Participant Name ______________________________ Exam Date ______________

Procedure Element	Yes	No
1. The tester has a copy of the current procedure on hand?	❒	❒
2. All equipment is functioning according to the test procedure, and if required, has the current calibration/verification tags present?	❒	❒
3. Sample reduced to correct size, if needed?	❒	❒
4. Sample dried and cooled, if necessary?	❒	❒
5. Sample properly sieved through specified sieve(s)?	❒	❒
6. Particles separated into fractured, unfractured, and questionable categories?	❒	❒
7. Dry mass of each category determined to nearest 0.1 g?	❒	❒
8. Calculation performed correctly?	❒	❒

First attempt: Pass ❒ Fail ❒ Second attempt: Pass ❒ Fail ❒

Signature of Examiner ______________________________

Comments:

WSDOT Test Method T 429

Retroreflectance of Newly Applied Pavement Marking Using Portable Hand-Operated Instruments

1. SCOPE

   This test method outlines the procedure for measuring the retroreflective properties of horizontal pavement marking materials containing retroreflecting beads, such as traffic stripes and surface symbols, using a portable retroreflectometer. Pavement markings must be checked for retroreflectivity within 14 days of application.

2. REFERENCES

   2.1. ASTM E 1710 Measurement of Retroreflective Pavement Marking Materials with CEN-Prescribed Geometry Using a Portable Retroreflectometer

   2.2. WSDOT Test Method T 716 Method of Random Sampling for Location of Testing and Sampling Sites

   2.3 CEN EN 1436 Road Marking Materials—Road Marking Performance for Road Users

3. APPARATUS

   3.1 Portable retroreflectometer meeting the requirements of ASTM E 1710

4. TEST LOCATIONS

   4.1 Testing locations will be selected at random by WSDOT Test Method T 716

   4.2 Solid Longitudinal Lines

   4.2.1 Road Lengths < 1000 Feet
   Randomly select one test location of pavement marking for testing.

   4.2.2 1000 Feet < Road Lengths < One Mile
   Randomly select two test locations of pavement marking for testing.

   4.2.3 One Mile < Road Length < Six Miles
   Randomly select three test locations: near the start, near the midpoint and near the end of the project.

   4.2.4 Road Length > Six Miles
   Randomly select test locations: near the start and end of the project and at random intervals of approximately every 2 miles within the length of the project.

4.3 Broken Longitudinal Lines

4.3.1 Road Lengths < 1000 Feet
Randomly select one test location of pavement marking for testing.

4.3.2 1000 Feet < Road Lengths < One Mile
Randomly select two test locations of pavement marking for testing.

4.3.3 One Mile < Road Length < Six Miles
Randomly select three test locations: one near the start, one near the midpoint and one near the end of the project.

4.3.4 Road Length > Six Miles
Randomly select test locations near the start and end of the project and at random intervals of approximately every 2 miles within the length of the project.

Note: If the random test location does not fall on a line, the marking closest to the random location will be tested.

5. TESTING LOTS

5.1. Each test location shall be divided into lots as follows:

5.1.1 Divided multi-Lane Two Way Roadways

WHITE -Each edge-line will be a lot.

WHITE -Each lane line will be a lot.

YELLOW -Each edge line will be a lot.

Other non-continuous lines included in the test location (i.e. Drop lane lines, channelizing lines, etc.) shall be included with existing lots by material type, line type and color. If these lines cannot be matched with other lines they shall be a separate lot.

Lines on ramps that are included in the test location shall be included with existing lots by material type, line type and color. If these lines cannot be matched with other lines they shall be a separate lot.

5.1.2 Undivided Two and Four Lane Two Way Roadways with Center Turn Lane

WHITE- Each edge line will be a lot

WHITE- Each lane line will be a lot

YELLOW-Each combination of solid and broken centerline will be a lot

Other non-continuous lines included in the test location (i.e. drop lane lines, channelizing lines, and etc.) shall be included with existing lots by material type, line type and color. If these lines cannot be matched with other lines they shall be a separate lot.

5.1.3 Undivided Four lane and Two Lane Two Way Roadways with or without channelization

WHITE- Each edge line will be a lot

WHITE- Each lane line will be a lot.

YELLOW-Any centerline combination (broken and or solid) will be a lot

Other non-continuous lines included in the test location (i.e. drop lane lines, channelizing lines, and etc.) shall be included with existing lots by material type, line type and color. If these lines cannot be matched with other lines they shall be a separate lot.

6. MEASUREMENT PROCEDURE

6.1 Take retroreflectivity measurements between 7 and 14 days of pavement marking application

6.2 Check pavement marking surface to see that it is clean, dry and free of any loose retroreflective media. If loose media is found, remove it by using a strong brushing motion with a broom, air pressure or any other method that doe not damage the correctly embedded spheres.

6.3 Standardize and operate the retroreflectometer per manufacture's recommendations.

6.4 Measurements will be taken at each test location as follows:

6.4.1 Divided multi-Lane Two Way Roadways

Edge lines - Take ten measurements spaced a minimum of ten feet apart on each edge line within 200 feet of the of the random test location. All measurements will be taken in the direction of traffic. Measurements for lots will be recorded and kept separate.

Lane lines - Take ten measurements, two on each of five broken line segments, within 200 feet of the of the random test location. All measurements will be taken in the direction of traffic. Measurements for lots will be recorded and kept separate.

Other non-continuous lines and ramp lines as described in 5.2.1 above. Ten measurements will be taken on each line.

6.4.2 Undivided Two and Four Lane Two Way Roadways with Center Two-Way Left-Turn Lane or Undivided Four lane and Two Lane Two Way Roadways with channelization

Edge lines - Take ten measurements spaced a minimum of ten feet apart on each edge line within 200 feet of the of the random test location. All measurements will be taken in the direction of traffic. Measurements for lots will be recorded and kept separate.

Lane lines - Take ten measurements, two on each of five broken line segments, within 200 feet of the of the random test location. All measurements will be taken in the direction of traffic. Measurements for lots will be recorded and kept separate.

Yellow Centerlines - Take five measurements within 200 feet of the of the random test location on each line (broken or solid) in one direction then turn the retroreflectometer 180 degrees and take five more measurements on each line in the other direction. Measurements for lots will be recorded and kept separate.

Other non-continuous lines as described in 5.2.2 and 5.2.3 above - Ten measurements will be taken on each line.

7. REPORT

7.1 Report the following information:

Contract number

Test date

Inspector name

Identification of the instrument used.

Value and date of standardization of the instrument standard panel used.

Ambient temperature

Milepost of test locations

Lot description by test location, lot number, type of line, color, material, date of installation and bid item number of the pavement marking

Print out of retroreflectometer readings for each lot at each test location per section, expressed as millicandelas per square meter per lux (mcd•m−2•lx−1). Include GPS coordinates for each retroreflectometer reading.

Remarks concerning the overall condition of the line, such as rubber skid marks, carryover of asphalt, snow plow damage, and other factors that may affect the retroreflection measurement.

Washington State
Department of Transportation

WSDOT Test Method T 606

Method of Test for Compaction Control of Granular Materials

1. SCOPE

    a. This test method is used to establish the theoretical maximum density of granular materials and non-granular materials with more than 30% by weight of the original specimen is retained on the No. 4 Sieve or more than 30% by weight of the original specimen is retained on the ¾” sieve.

    b. There are three separate tests in this method which present a method for establishing the proper theoretical maximum density values to be used for controlling the compaction of granular materials. These tests account for variations of the maximum obtainable density of a given material for a given compactive effort, due to fluctuations in gradation.

    c. By splitting the material on the U.S. No. 4 (4.75 mm) sieve and determining the specific gravity, the compacted density, and the loose density of each of the two fractions, a curve of theoretical maximum density versus percent passing the U.S. No. 4 (4.75 mm) sieve can be plotted. These curve values will correlate closely with the densities obtained in the field; using modern compaction equipment.

    d. Table 1 identifies the Test, Method or Procedure to use in performing T 606. The table is divided into the Fraction of the split (Fine or Coarse) and the material type of that Fraction.

Test Method Selection Table	
Fine Material	
Soil Type	**Test Method**
Sandy, Non-plastic, permeable	T606 Test 1
Silt, some plasticity, low permeability	T 99 Method A
Sandy/silt, some plasticity, permeable	T 606 Test 1/T 99 Method A (use highest results)
Coarse Material	
No more than 15% by weight of original aggregate specimen exceeds ¾ in (19 mm)	T 606 Test 2 Procedure 1
15% or more % by weight of original aggregate specimen is greater than ¾ in. (19 mm), but does not exceed 3 in. (76 mm)	T 606 Test 2 Procedure 2

Table 1

e. The test methods are applicable either to specifications requiring compacting to a given percentage of theoretical maximum density, or to specifications requiring compaction to a given compaction ratio.

f. Use of these test methods eliminates the danger of applying the wrong "Standard" to compaction control of gravelly soils.

g. Native soils within the contract limits to be used for embankment construction and/or backfill material do not require the sampling by a qualified tester. For material that requires gradation testing such as but not limited to manufactured aggregates and Gravel Borrow, a qualified testers shall be required for sampling.

Test No. 1

(Fine Fraction-l00 Percent Passing U.S. No. 4 (4.75 mm) Sieve)

1.1 SCOPE

a. This test was developed for the sandy, non-plastic, highly permeable soils which normally occur as the fine fraction of granular base course and surfacing materials.

b. When the fine fraction is primarily a soil having some plasticity and low permeability, AASHTO T 99 (Standard Proctor Test) may be used. With borderline soils, both tests should be applied and the one yielding the highest density value should be used.

1.2 APPARATUS

a. Vibratory, Spring Load Compactor — Specifications for vibratory spring load compactor can be obtained from the State Materials Lab.

b. Mold — Molds can be fabricated from standard cold drawn-seamless piles or tubes. The dimensions for the small mold are; height 8 in (± 0.002 in), ID 6 in (± 0.002 in). The wall thickness of the mold shall be no less than ¼ in. The mold has a bottom plate which attaches to the mold and is slightly larger than the outer diameter of the mold. The small button at the center of the small mold follower is a measuring point. The height of this button should be adjusted so the machine follower does not bear on it during compaction.

c. Mold Piston — A piston which has a bottom face diameter of 5 ⅞ in. (150 mm) OD and an overall height of 2 in. The top of the piston shall have a 2 ¼ in ID.

d. Height-Measuring Device — A scale with an accuracy of 0.01 in. (0.25 mm).

e. Tamping Hammer — As specified in AASHTO T 99, Section 2.21.

f. Sieve — U.S. No. 4 (4.75 mm) sieve.

g. Oven — Capable of maintaining a temperature of 230° ± 5°F (110 ± 5° C) for drying moisture specimens.

h. Balance — A balance having a capacity of100 lbs. (45 kg) and a minimum accuracy of 0.1 lbs. (50 g).

i. Tamping Rod — ⅝ in. (16 mm) spherical end.

1.3 PROCEDURE

a. Oven-dry the total original sample at a temperature not to exceed 140°F (60°C).

b. Obtain tare weight of mold and bottom plate, record weight (mass) to the nearest 0.01 lb. (5 g) or less if using a balance that is more accurate than 0.1 lbs.

c. Sieve the entire specimen over a No. 4 (4.75 mm) sieve to separate the fine and coarse material. Retain the coarse material for the second half of the procedure (T 606 Test 2).

d. Split the No. 4 minus material in accordance with WSDOT FOP for AASHTO T 248 to obtain a representative specimen of approximately 13 lbs. (6 kg). (This mass can be adjusted after the first compaction run to yield a final compacted specimen approximately 6 in. (150 mm) high.)

e. Estimate the optimum moisture for the material. Calculate the mass of water required for optimum moisture and add water to specimen.

Weight of Water

Equation: *Wt. of water = (decimal percent water)(mass dry sample)*

f. Mix the specimen until the water and dry material are thoroughly and completely mixed.

g. Place the specimen in the mold in three layers. Rod each layer 25 times and tamp with 25 blows of the tamping hammer. The blows of the hammer should produce a 12 in. (305 mm) free fall provided severe displacement of the specimen does not occur. In such cases, adjust the blow strength to produce maximum compaction. The surface of the top layer should be finished as level as possible.

h. Place the piston on top of the specimen in the mold, and mount the mold on the jack in the compactor. Elevate mold with the jack until the load-spring retainer seats on top of the piston. Apply initial seating load of about 100 lbs. (45 kg) on the specimen.

i. Start the compactor hammers and, at the same time, gradually increase the spring load on the specimen to 2,000 lbs. (908 kg) by elevating the jack in accordance with Table 2.

j. Check the mold for specimen saturation. The specimen is considered saturated when, free water (a drop or two of water) shows at the base of the mold. If water is not present at the base of the mold within the first 1½ minutes stop the test, remove the specimen from the mold and repeat 1.3 e-j. The specimen can be reused for subsequent water contents providing it is not a fragile material.

k. Caution: Most materials will yield the highest density at the moisture content described above. Some materials may continue to gain density on increasing the moisture above that specified; however, severe washing-out of the fines will occur, which will alter the character of the sample and void the test results.

l. If moisture is observed at the base of the mold continue applying loads at the following rates:

Load in lbs (kg)	Time in Minutes
100 to 500 lbs. (0 to 227)	1
500 lbs. to 1,000 lbs. (227 to 454)	½
1,000 lbs. to 2,000 lbs. (454 to 908)	½

Rate of Load Application
Table 2

m. After reaching 2,000 lbs. (908 kg), stop the hammers, release the jack, and return to zero pressure.

n. Repeat step h. four additional times; remove the mold from the compactor.

0. Measure and record the height of the compacted specimen to the nearest 0.01 in. (.25 mm) and calculate the volume (see Section 1.4)

p. Remove the specimen from the mold, weigh it, and record its mass (weight) to the nearest 0.01 lbs. (5 g), and calculate the wet density.

q. Vertically slice through the center of the specimen, take a representative specimen (at least 1.1 lbs. (500 g)) of the materials from one of the cut faces (using the entire specimen is acceptable), weigh immediately, and dry in accordance with AASHTO T 255 to determine the moisture content, and record the results. Calculate and record the dry density.

r. Repeat steps d. through m. at higher or lower moisture contents, on fresh specimen if needed, to obtain the theoretical maximum density value for the material, three tests are usually sufficient.

1.4 CALCULATIONS

a. The formula for calculating the volume and dry and wet densities are as follows:

V =

H1 = Inside height of the mold, in (mm).

H2 = Height from top of the specimen to the top of the mold, in (mm).

B = Inside bottom area of the mold, in^2 (mm^2)

Wet Density =

Dry Density =

*Note: See AASHTO T 255-00"Total Moisture Content of Aggregate by Drying," for moisture content calculations.

Test No. 2

(Coarse Fraction-100 Percent Retained on the U.S. No. 4 (4.75 mm) Sieve)

2.1 SCOPE

a. This test is used when there is 100 percent retained on the U.S. No. 4 (4.75 mm) sieve. There are two separate procedures based on the maximum size of the aggregate being tested. Procedure 1 is used when no more than 15% by weight of the original specimen of the coarse aggregate exceeds ¾ in. (19 mm). Procedure 2 is used when 15% or more by weight of the original specimen of the aggregate is greater than ¾ in. (19 mm), but does not exceed 3 in. (76 mm). If there is any aggregate greater than 3 in. (76 mm), it has to be removed before proceeding with the test.

Procedure 1

(Aggregate Size: No. 4 to ¾ in. (19 mm)

2.2 EQUIPMENT

a. The apparatus for this test is the same as that used in Test No. 1

2.3 PROCEDURE

a. From the coarse split obtained in Test No. 1, Section 1.3(C), separate a representative specimen of 10 to 11 lbs. (4.5 to 5 kg) and weigh to 0.01 lbs. (5 g), or less if using a balance that is more accurate than 0.1 lbs.

b. Dampen the specimen to 2 ½% moisture and place it in a 0.1 $ft.^3$ (0.0028 m^3) mold, in three lifts. Tamp each lift lightly to consolidate the material to achieve a level surface. Omit rodding. Avoid loss of the material during placement.

c. Place the piston on top of the specimen in the mold, and mount the mold on the jack in the compactor. Elevate mold with the jack until the load-spring retainer seats on top of the piston. Apply initial seating load of about 100 lbs. (45 kg) on the sample.

d. Start the compactor hammers and, at the same time, gradually increase the spring load on the sample to 2,000 lbs. (908 kg) by elevating the jack in accordance with the Table 2.

e. Follow procedure described in Test No. 1 Section 1.3 m through 1.3 r.

f. Using the original dry weight value, calculate the dry density in lb/ft3 (kg/m3). Use the formula for dry density described in Test No.1, Section 1.4.

Procedure 2

(Aggregate Size: No. 4 to 3 in. (76 mm))

2.4 EQUIPMENT

a. ½ ft.^{3} (0.014 m^3) standard aggregate measure.

b. A metal piston having a diameter ⅛ in. (3 mm) less than the inside diameter of the ½ ft.^{3} (0.014 m^3) measure.

2.5 PROCEDURE

a. From the coarse fraction in Test No. 1, Section 1.3c., separate a representative specimen of 45 lb. (20 kg) and weigh to 0.1 1b. (50 g), or less if using a balance that is more accurate than 0.1 lbs.

b. Split the specimen into five representative and approximately equal parts.

c. Place the specimen in the mold in five separate lifts after each lift is placed in the mold, position the piston on the specimen, mount the mold in the compactor, and compact as described in Table 2, Section 1.3h. Spacers between the load spring and piston must be used to adjust the elevation of the mold to the height of the lift being compacted.

d. After the final lift is compacted, remove the mold from the compactor, determine the height of the compacted specimen, and calculate the volume (see Test No. 1, Section 1.4(a)).

e. Calculate the dry density in lbs./ft.^{3} (kg/m^3) (see Test No. 1, Section 1.4(a)).

Test No. 3

Specific Gravity Determination for Theoretical Maximum Density Test

3.1 EQUIPMENT

a. Pycnometer calibrated at the test temperature having a capacity of at least 1 quart (100 ml).

b. One vacuum pump or aspirator (pressure not to exceed 100 mm mercury).

c. One balance accurate to 0.1 g.

3.2 MATERIAL

a. Fine fraction U.S. No. 4 (4.75 mm) minus 1.1 lbs. (500 g) minimum.

b. Coarse fraction U.S. No. 4 (4.75 mm) plus 2.2 lbs. (1,000 g) minimum.

3.3 PROCEDURE

a. Place dry material, either fine or coarse fraction, in pycnometer, add water. Put pycnometer jar top in place and connect to vacuum apparatus. Apply vacuum for at a minimum of 20 minutes until air is removed from specimen. Slight agitation of the jar every 2 to 5 minutes will aid the de-airing process. If the material boils too vigorously, reduce the vacuum. Remove vacuum apparatus, fill pycnometer with water, dry outside of jar carefully and weigh. Water temperature during test should be maintained as close to 68° ± 1°F (20° ± 0.5°C) as possible.

Calculate Specific Gravity as follows:

Sp. Gr. =

Where:
a = Weight of dry material, grams
b = Weight of pycnometer + water, grams
c = Weight of pycnometer + material + water, grams

3.4 REPORTS

a. All test results are recorded on the theoretical maximum density work sheet.

b. Use the appropriate computer program to determine the theoretical maximum density.

Performance Exam Checklist

Method of Test for Compaction Control of Granular Materials
WSDOT Test Method T 606

Participant Name Exam Date

Procedure Element	Yes	No
1. The tester has a copy of the current procedure on hand?	❒	❒
2. All equipment is functioning according to the test procedure, and if required, has the current calibration/verification tags present?	❒	❒
FINE FRACTION — 100% PASSING THE US NO. 4 (4.75 MM) SIEVE		
Specimen Preparation		
1. Has the specimen been oven-dried?	❒	❒
2. Has the specimen been separated on the US No. 4 (4.75 mm) sieve?	❒	❒
3. Is the specimen weight approximately 13 lbs?	❒	❒
Procedure		
1. Is specimen saturated when compacted?	❒	❒
2. Has specimen been placed in three layers, rodded 25 and tamped 25 times, each layer?	❒	❒
3. Is the hammer blow approximately a 12 inch free fall to prevent severe displacement of the specimen?	❒	❒
4. The specimen is as level as possible?	❒	❒
5. Has piston been placed on top of the specimen?	❒	❒
6. Has the mold been mounted on the jack in the compactor?	❒	❒
7. Has the mold been elevated until the load-spring retainer sits on top of the piston?	❒	❒
8. Has the initial load been set at 100 pounds?	❒	❒
9. Is the loading rate applied as specified in the test procedure?	❒	❒
10. Has the hammer been stopped, jack released, and pressure returned to zero when 2,000 pounds pressure was reached?	❒	❒
11. Steps 7 through 10 repeated four additional times?	❒	❒
12. Is free water present at the base of the mold within 1½ minutes of the start of the first compression run?	❒	❒
13. The mold removed from the compactor?	❒	❒
14. Has the height of the specimen been determined?	❒	❒

Procedure Element	**Yes**	**No**
15. Has specimen been weighed?	❒	❒
16. Has specimen been removed from mold and a representative portion immediately weighted and the moisture percentage determined?	❒	❒
17. Moisture content, dry density determined and entered on the testing sheet?	❒	❒
18. Theoretical maximum density determined by testing fresh specimens, as necessary, at different moisture contents and entered on the testing sheets?	❒	❒

AGGREGATE SIZE: NO. 4 TO ¾ IN. (19 MM)

Specimen Preparation

1. Has the specimen been oven-dried?	❒	❒
2. Has the specimen been separated on the US No. 4 (4.75 mm) sieve?	❒	❒
3. Does more than 85% of the material pass the ¾ in. (19 mm) sieve?	❒	❒
4. Does more than 85% of the material pass the ¾ in. (19 mm) sieve?	❒	❒

Procedure

1. Weight and record specimen weight?	❒	❒
2. Has the specimen been dampened to 2½ percent and placed in a 0.1ft^3 mold and placed in three lifts?	❒	❒
3. The specimen is tamped lightly to archive a level surface?	❒	❒
4. Piston placed on top of specimen and mold mounted on jack in compactor?	❒	❒
5. Mold elevated until the load-spring retainer sits on top of the piston?	❒	❒
6. Initial load of 100 lbs set prior to starting machine?	❒	❒
7. Is the load rate applied as specified in the test procedure?	❒	❒
8. Hammers stopped, jack released, and pressure returned to 100 pounds when 2000 pound load has been reached?	❒	❒
9. Steps 5 and 6 repeated four additional times?	❒	❒
10. The mold removed from the compactor and the height measured?	❒	❒
11. Dry density calculated and entered on the testing sheets?	❒	❒

AGGREGATE SIZE: NO. 4 TO 3 IN.

Specimen Preparation

1. Has the specimen been oven-dried?	❒	❒
2. Has the specimen been separated on the US No. 4 (4.75 mm) sieve?	❒	❒
3. Is the specimen weight approximately 45 lbs?	❒	❒
4. Does the specimen contain 15% or more ¾ + material?	❒	❒
5. Has material greater than 3 in. (76 mm) been removed?	❒	❒
6. Specimen separated into 5 approximately equal parts?	❒	❒

Procedure Element	**Yes**	**Yes**
Procedure		
1. Specimen place in the mold in five separate lifts?	❒	❒
2. The specimen is as level as possible?	❒	❒
3. After each lift, mold placed in compactor and compacted according to test procedure?	❒	❒
4. After compacting final lift, specimen removed from compactor and volume determined?	❒	❒
5. Dry density determined calculated and entered onto testing sheet?	❒	❒
SPECIFIC GRAVITY DETERMINATION FOR THEORETICAL MAXIMUM DENSITY TEST		
Specimen Preparation		
1. Has the specimen been oven-dried?	❒	❒
2. Has the specimen been separated on the US No. 4 (4.75 mm) sieve?	❒	❒
3. Weight of fine fraction approximately 500g?	❒	❒
4. Weight of coarse fraction approximately 1000g?	❒	❒
Procedure		
1. Material placed in pycnometer and water at 68°F added?	❒	❒
2. Vacuum applied for at least 20 minutes?	❒	❒
3. Container and contents agitated manually by shaking at intervals of about 2 to 5 minutes?	❒	❒
4. Pycnometer filled with water at 68°F?	❒	❒
5. Pycnometer dried, weighted, and recorded on testing sheet?	❒	❒
6. Specific Gravity calculated and entered onto testing sheet?	❒	❒

First attempt: Pass ❒ Fail ❒ Second attempt: Pass ❒ Fail ❒

Signature of Examiner

Comments:

WSDOT Standard Operating Procedure SOP 615

Determination of the % Compaction for Embankment & Untreated Surfacing Materials using the Nuclear Moisture-Density Gauge

1. SCOPE

   This procedure covers the procedures for determining the in-place density, moisture content, gradation analysis, oversize correction, and determination of maximum density of compacted soils and untreated surfacing materials using a nuclear density device in the direct transmission mode.

2. REFERENCES

   a. WSDOT FOP for AASHTO T 99 for Method of Test for Moisture-Density Relations of Soils

   b. WSDOT FOP for AASHTO T 180 for Method of Test for Moisture-Density Relations of Soils

   c. WSDOT FOP for AASHTO T 224 for Correction for Coarse Particles in Soil Compaction Test

   d. WSDOT FOP for AASHTO T 255 for Total Moisture Content of Aggregate by Drying

   e. WSDOT FOP for AASHTO T 272 for Family of Curves — One Point Method

   f. WSDOT FOP for AASHTO T 310 for In-Place Densities and Moisture Content of Soils and Soil-Aggregate by Nuclear Methods (Shallow Depth)

   g. WSDOT T 606 Method of Test for Compaction Control of Granular Materials

3. TEST LOCATION

   When selecting a test location, the tester shall visually select a site where the least compactive effort has been applied. Select a test location where the gauge will be at least 6 in. (150 mm) away from any vertical mass. If closer than 24 in. (600 mm) to a vertical mass, such as in a trench, follow gauge manufacturer correction procedures.

   Note: *When retesting is required due to a failing test; retest within a 10 foot radius of the original station and offset.*

4. NUCLEAR DENSITY TEST

   Determine the dry density and moisture content of soils and untreated surfacing materials using the nuclear moisture-density gauge in accordance with WSDOT FOP for AASHTO T 310, and record on DOT Form 350-074 “Field Density Test”

5. OVERSIZE DETERMINATION

a. WSDOT FOP AASHTO T 99 and WSDOT T 606

A sample weighing a minimum of 9 lbs. will be taken from beneath the gauge. Care shall be taken to select material that is truly representative of where the moisture density gauge determined the dry density and moisture content.

There are two methods for determining the percentage of material retained on the No. 4 sieve:

Method 1

1. Dry the sample to SSD conditions, (i.e. dried until no visible free moisture is present, material may still appear damp). Allow the sample to cool sufficiently and record mass to the nearest 0.1 percent of the total mass or better.
2. Shake sample by hand over a verified No. 4 (4.75 mm) sieve. Limit the quantity of material on the sieve so that all particles have the opportunity to reach the sieve openings a number of times during the sieving operation. The mass retained on the No. 4 (4.75 mm) sieve at the completion of the sieving operation shall not exceed 800 grams, 1.8 pounds, for the 12" sieve, or 340 grams, 0.75 pounds; for the 8" sieve.
3. Remove and weigh the material on the No. 4 (4.75 mm) sieve to the nearest 0.1% of the total mass or better and record.

Notes: This method is only recommended for crushed surfacing materials, materials with high clay content, or other granular materials that are at or near the optimum moisture content for compaction.

Method 2:

1. Determine the mass of the sample to the nearest 0.1% of the total mass or better and record.
2. Charge the material in a suitable container with water, agitate the material to suspend the fines, then slowly decant and screen the material over a verified No. 4 (4.75 mm) sieve. Repeat the process as necessary to remove as much No. 4 (4.75 mm) minus material as possible. DO NOT overload the sieve.
3. Place the washed sample retained on the No. 4 (4.75 mm) sieve into a tared container. Blot the material to a SSD condition (i.e. no visible free moisture present, material may still appear damp) during this step.
4. Weigh the mass of the material on the No. 4 (4.75 mm) sieve to the nearest 0.1% of the total mass or better and record.

b. WSDOT FOP AASHTO T 180

Follow ~~the~~ either Method 1 or Method 2 in 5 a. with the following exception; sieve the material over a ¾ in (19.0 mm) sieve.

6. CALCULATION OF PERCENT RETAINED AND PERCENT PASSING

To calculate the percent retained use, the mass retained on the No. 4 when performing test methods T 99 and T 606 and the mass retained on the ¾" sieve when performing test method T 180.

$$\% \text{ retained on sieve} = 100 \times \frac{\textit{Mass retained}}{\textit{Mass dry or SSD sample}} \quad \text{(round to nearest percent)}$$

% passing sieve = 100 - % retained on sieve

7. CALCULATING PERCENT COMPACTION

Determine the corrected theoretical maximum density by using values from the Density Curves table of the soils report. In the table use the percent passing value to enter the table, read across to the column labeled Max use this number as the Corrected Theoretical Maximum Density in the equation below. Calculate the percent of compaction using the following equation:

$$\% \text{ Compaction} = \frac{\text{Dry Density (lbs/ft}^3\text{) x 100}}{\text{Corrected Theoretical Maximum Density (lbs/ft}^3\text{)}}$$

8. REPORT

Report data on DOT Form 350-074, "Field Density Test" and on DOT Form 351-015 "Daily Compaction Test, or other report approved by the State Materials Engineer.

Report the percent of compaction to the nearest whole number.

Performance Exam Checklist

WSDOT Standard Operating Procedure SOP 615
Determination of the % Compaction for Embankment & Untreated Surfacing Materials using the Nuclear Moisture-Density Gauge

Participant Name ______________________________ Exam Date ______________

Procedure Element	**Yes**	**No**
1. The tester has a copy of the current procedure on hand?	❒	❒
2. All equipment is functioning according to the test procedure, and if required, has the current calibration/verification tags present?	❒	❒
Gradation Analysis		
3(A) Method 1		
1. Sample Dried to a SSD condition (dried until no visible free moisture present) and mass recorded?	❒	❒
2. Sample allowed to cool sufficiently prior to sieving?	❒	❒
3. Sample was shaken by hand through the appropriate sieve for a sufficient period of time?	❒	❒
4. Recorded mass of material retained on the appropriate sieve?	❒	❒
5. Calculated and recorded percent of material retained and passing the appropriate sieve?	❒	❒
3(B) Method 2		
1. Mass of sample determined prior to washing?	❒	❒
2. Material charged with water in suitable container and agitated to suspend fines?	❒	❒
3. Sample decanted over required sieve for a sufficient amount of time without overloading sieve?	❒	❒
4. Retained material dried to SSD condition and mass determined?	❒	❒
5. Recorded mass of material retained on appropriate sieve?	❒	❒
6. Calculated and recorded percent of material retained and passing appropriate sieve?	❒	❒
Correction for Coarse Particles		
7. Appropriate computer-generated chart used to determine the corrected theoretical maximum density, based on the percent retained on the appropriate sieve?	❒	❒
8. All calculations performed correctly?	❒	❒

First attempt: Pass ❒ Fail ❒ Second attempt: Pass ❒ Fail ❒

Signature of Examiner ______________________________

Comments:

Washington State
Department of Transportation

WSDOT Test Method T 716

Method of Random Sampling for Locations of Testing and Sampling Sites

1. SCOPE
   a. This method outlines the procedure for selecting sampling and testing sites in accordance with accepted random sampling techniques. It is intended that all testing and sampling locations be selected in an unbiased manner based entirely on chance.
   b. Testing and sampling locations and procedures are as important as testing. For test results or measurements to be meaningful, it is necessary that the sampling locations be selected at random, typically by use of a table of random numbers. Other techniques yielding a system of randomly selected locations are also acceptable.
   c. This procedure is divided into several sections:
      - Applications for Hot Mixture Asphalt Density
      - Applications for Hot Mixture Asphalt (HMA) Sampling
      - Applications for Portland Cement Concrete
      - Applications for Aggregate and other materials
2. PROCEDURE
   a. Determine the lot, or sublot size and number of tests required for material being tested or sampled.
   b. Select a two digit number at random. Use the random number as the entry point into the random number table.

      Note: A recommended procedure for selecting a random number is stated in each of the categories of material in Section 4 Calculations.
   c. Determine multipliers for testing/sampling locations using Table 1 to calculate “X” and “Y” coordinates or Table 2 to calculate tonnage (X only).
3. CALCULATIONS
   a. Hot Mix Asphalt Density
      1. To determine a testing site location, calculate the tons/linear foot distance as follows:

$$\text{Tons per linear foot} = \frac{1.0\text{ ft} * \text{width (feet)} * \text{depth (feet)}) * 2.05\text{ Tons/cy}}{27}$$

$$\text{Sublot length} = \frac{tons}{tons\ per\ linear\ ft}$$

Example:

Pavement-12 ft wide, 0.15 ft deep, 80 ton sublot

$$\text{Tons per linear Foot} = \frac{1.0\text{ ft} * 12\text{ ft} * 0.15\text{ ft} * 2.05\text{ tons}}{27} = 0.137\text{ Tons per linear Foot.}$$

$$\text{Sublot length} = \frac{80\text{ Tons}}{0.137\text{ Tons per linear Foot}} = 583.9\ \text{ lf (round to 584 lf)}$$

2. Choose a number at random (see section 3b) to enter Table 1. The recommended method for choosing a random number for HMA density is to use the last two digits from the most recent standard count on the nuclear gauge.
3. Determine the test station and offset as follows:

   Test Station = (sublot length * "X" multiplier) + beginning station of paving

   Offset (from right side of pavement) = (width of pavement * "Y" multiplier)

   Note: The values in the table have been set so that no measurements are taken within 1.5 LF of the edge of the pavement. When a test falls within an area that is not appropriate for a test location (i.e. a bridge end, track crossing, night joint) move the testing location 25 lf ahead or back on stationing, as appropriate.

   Example:

   Beginning Station= 168 + 75

   Width = 12 ft

   Sublot length = 584

   Standard Count = 2951

   Beginning Test Location

   Enter table at line (51): "X" multiplier = 0.762, "Y" multiplier = 0.65

   Stationing = (584 * 0.762) + 16875 = 173 +20

   Offset = (12 * 0.65) = 7.8 ft

4. Determine subsequent testing locations as follows:

   Enter the random number table on the next line in sequence (if original table entry 51, next line entry 52, then 53, etc.)

   New beginning station = previous testing location + sublot length

   X coordinate = (sublot length * "X" multiplier) + New beginning station

   Y coordinate = (width of pavement * "Y" multiplier)

   Example:

   Second Test Location

   New beginning station = (173 +20) + 584 = 179 +04
   Enter table at line (52): "X" multiplier = 0.762, "Y" multiplier = 0.65
   Test station = (584 * 0.285) + 17904 = 180 +70
   Offset = (12 * 0.28) = 3.4 ft from right edge

Y values are selected so that lateral locations are no closer than 1.5 feet (0.45m) from the edge of a paving strip.											
Sequence	**X**	**Y**	**Sequence**	**X**	**Y**	**Sequence**	**X**	**Y**	**Sequence**	**X**	**Y**
1	0.290	0.33	26	0.657	0.69	51	0.762	0.65	76	0.434	0.43
2	0.119	0.43	27	0.761	0.27	52	0.285	0.28	77	0.832	0.71
3	0.694	0.32	28	0.389	0.69	53	0.347	0.87	78	0.044	0.73
4	0.722	0.47	29	0.751	0.20	54	0.962	0.75	79	0.235	0.28
5	0.784	0.39	30	0.191	0.77	55	0.203	0.60	80	0.271	0.62
6	0.953	0.15	31	0.006	0.50	56	0.803	0.35	81	0.477	0.85
7	0.576	0.14	32	0.456	0.23	57	0.672	0.17	82	0.267	0.44
8	0.069	0.74	33	0.367	0.85	58	0.306	0.20	83	0.933	0.28
9	0.691	0.86	34	0.025	0.73	59	0.223	0.83	84	0.974	0.87
10	0.973	0.44	35	0.299	0.33	60	0.116	0.58	85	0.600	0.46
11	0.328	0.5	36	0.194	0.25	61	0.768	0.32	86	0.591	0.19
12	0.468	0.78	37	0.936	0.37	62	0.893	0.37	87	0.165	0.77
13	0.183	0.44	38	0.231	0.71	63	0.504	0.66	88	0.668	0.41
14	0.669	0.36	39	0.050	0.74	64	0.043	0.31	89	0.327	0.29
15	0.971	0.71	40	0.584	0.43	65	0.284	0.39	90	0.473	0.51
16	0.336	0.37	41	0.172	0.87	66	0.196	0.15	91	0.598	0.58
17	0.314	0.78	42	0.430	0.87	67	0.742	0.66	92	0.373	0.69
18	0.508	0.44	43	0.704	0.19	68	0.941	0.43	93	0.244	0.24
19	0.347	0.20	44	0.009	0.18	69	0.531	0.31	94	0.831	0.14
20	0.877	0.85	45	0.552	0.17	70	0.478	0.56	95	0.178	0.45
21	0.712	0.17	46	0.626	0.29	71	0.228	0.37	96	0.821	0.46
22	0.193	0.17	47	0.144	0.62	72	0.008	0.48	97	0.124	0.62
23	0.976	0.69	48	0.246	0.13	73	0.002	0.17	98	0.580	0.57
24	0.997	0.63	49	0.055	0.40	74	0.330	0.42	99	0.037	0.24
25	0.930	0.44	50	0.678	0.66	75	0.089	0.20	100	0.700	0.59

Random Numbers with X and Y value
Table 1

b. HOT MIX ASPHALT (HMA) PAVEMENT MIXTURE

1. Determine the sublot increment of the material.
2. Choose a number at random to enter Table 2. The recommended method for choosing a random number for HMA mix is to use the last two digits of the ignition furnace calibration.
3. Determine the test location by tonnage.
4. Calculate the first test location as follows:

   Sampling Site = Sublot increment * “X” multiplier (Table 2)

   Example:

   The Ignition Furnace Calibration is 0.45%. Use 45 as the starting point to enter random number Table 2. “X”=0.604.

First test location:

Sublot increment = 800 tons
Beginning tonnage: 0
Sublot increment: 800 * 0.604 = 483
Test tonnage Sample 1: Beginning tonnage + 483 tons = 483 tons

Random sample tonnage may be adjusted per sublot to accommodate field testing. Adjustments to random sample tonnage should be documented.

e. Determine subsequent test locations as follows:

The new beginning tonnage is calculated by adding the sublot increment tonnage to the previous test tonnage.

Enter the Table 2 on the next line in sequence (if beginning entry 45, next line entry 46, next 47, etc.)

Example:

Second test location:

Enter Table 2 at (46) "X" = 0.087
Sublot increment: 800 * 0.087 = 70
Testing tonnage Sample 2: 800 + 70 = 870 tons

X	X	X	X	X
(1) 0.186	(21) 0.256	(41) 0.201	(61) 0.508	(81) 0.431
(2) 0.584	(22) 0.753	(42) 0.699	(62) 0.884	(82) 0.509
(3) 0.965	(23) 0.108	(43) 0.785	(63) 0.648	(83) 0.962
(4) 0.044	(24) 0.626	(44) 0.874	(64) 0.398	(84) 0.315
(5) 0.840	(25) 0.885	(45) 0.604	(65) 0.142	(85) 0.721
(6) 0.381	(26) 0.418	(46) 0.087	(66) 0.962	(86) 0.637
(7) 0.756	(27) 0.320	(47) 0.334	(67) 0.516	(87) 0.056
(8) 0.586	(28) 0.098	(48) 0.189	(68) 0.615	(88) 0.905
(9) 0.480	(29) 0.791	(49) 0.777	(69) 0.226	(89) 0.195
(10) 0.101	(30) 0.717	(50) 0.704	(70) 0.881	(90) 0.981
(11) 0.282	(31) 0.868	(51) 0.946	(71) 0.369	(91) 0.600
(12) 0.957	(32) 0.583	(52) 0.426	(72) 0.001	(92) 0.044
(13) 0.377	(33) 0.385	(53) 0.266	(73) 0.744	(93) 0.433
(14) 0.456	(34) 0.465	(54) 0.791	(74) 0.229	(94) 0.762
(15) 0.778	(35) 0.101	(55) 0.711	(75) 0.906	(95) 0.678
(16) 0.243	(36) 0.285	(56) 0.122	(76) 0.413	(96) 0.347
(17) 0.578	(37) 0.829	(57) 0.895	(77) 0.827	(97) 0.274
(18) 0.966	(38) 0.998	(58) 0.371	(78) 0.984	(98) 0.114
(19) 0.373	(39) 0.539	(59) 0.221	(79) 0.641	(99) 0.480
(20) 0.834	(40) 0.060	(60) 0.011	(80) 0.068	(100) 0.685

Random Numbers
Table 2

c. PORTLAND CEMENT CONCRETE (PCC)

1. Determine the sublot increment for the random test sample. A sublot for PCC is based on a sampling frequency of one in five trucks after, two successive trucks within specification.

   Sublot increment = Cubic Yards per truck * 5 trucks

   Example

   Each truck carries 10 CY of concrete

   Sublot Increment = 10 CY * 5 trucks = 50 CY

2. Choose a two digit number at random to enter Table 2. The recommended method for choosing a random number for Portland Cement Concrete is to choose the last two digits from the first civilian license plate seen that day (do not use vehicles associated with the project site).

   Note: Start each day of concrete placement with an new “X” value determined by chance in order to obtain a random selection

3. Determine the sample location as follows:

   Sampling Location = Sublot increment * “X” multiplier (Table 2)

   Example:

   The civilian license plate ends in 37. Use 37 as the starting point to enter random number Table 2 “X”= 0.829.

   Sample location = 50 CY x 0.829 = 41 CY

4. Determine where the first sample will be taken:

   Sample Yardage = (CY per truck * 2 (for the first two trucks)) + Sample location

   Example:

   First sample location:
   Sample location = (10 CY *2) + 41 CY = 61 CY

5. The sample will be taken from the truck containing the 61st CY or in this example the seventh truckload of the pour. Allow approximately ½ CY of concrete to be discharged before sampling the truck.

   Example

   (41 /10) CY= 4.1 trucks + original 2 truck = 6.1 trucks

   Sample is located in the first 1/3 of the 7th truck of the pour.

6. Determine subsequent sampling locations as follows:

   Example:

   Second sample location:
   Use the next sequential line of the chart after the beginning random number. Original number was 37 use line (38) as the starting point to enter random number Table 2. "X"= 0.998.

   Sample location = 50 CY x 0.998 = 49.9 CY = 50 CY

7. The second sample will be taken at 120 CY

   Example

   20 CY (first two trucks) + 50 (first random sample of 5 trucks) + 50 CY

   The sample would come from the last ⅓ of the truck 12th truck of the pour.

d. AGGREGATE AND OTHER MATERIALS

1. Determine the lot or sublot size according to the contract documents. The lot or sublot shall be determined to the nearest 100 tons.

2. Choose a two digit number at random to enter Table 2. The recommended method for choosing a random number for Aggregates and other materials not described above is to choose the last two digits from the first civilian license plate seen that day (do not use vehicles associated with the project site) or use a digital stopwatch. To use the stop watch method; start the stop watch and let it count for several seconds, stop the watch and use the decimal part of the seconds as your entry point.

3. Determine the sample location as follows:

   Sampling Location = lot or Sublot size * "X" multiplier (Table 2)

   Sampling from a Belt or Flowing Stream: The specification calls for one sample from every 1000 Tons of aggregate. If the random number is (58), "X"= 0.371,

   Example:

   First sample location

   (0.371) (1000 Tons) = 371 Tons.

   Sample the material when the 371th ton passes over the belt.

   Second sample location

   Entry line will be (59), "X"= 0.221

   (0.221) (1000 Tons) = 221 Tons

   Sample site= 371 + 221 = 592

   Sample the material when the 592nd ton passes over the belt.

   Sampling from Haul Units: If the contract documents require samples based on number of haul units. Determine the number of hauling units that comprise a lot. Multiply the selected random number(s) by the number of units to determine which unit(s) will be sampled.

Example:

Lot size = 20 haul units

If the random number is (58), "X"= 0.371,

First sample location

(0.371) (20) = 7.42 haul units.

Sample is taken from the 7th haul unit

Second sample location

Entry line will be (59), "X"= 0.221

(0.221) (20) = 4.42 haul units

Sample site= 20 + 4.42 = 24.42

Sample the material when the 24th haul unit

Sampling from a Roadway with Previously Placed Material: Determine the sample location in the same manner as Section 4 (A) Hot Mix Density.

APPPENDIX A

HOT MIX ASPHALT DENSITY AND CHALLENGE CORES (400 TON LOTS)

a. Determine the LOT size and number of tests per LOT. The Standard specifications set the size of a density test lot for Hot Mix Asphalt Pavement to no greater than a single day’s production or 400 tons, whichever is less, and require five tests per LOT. At the end of a day's production the final lot may be increased to a maximum of 600 tons.

b. Convert this LOT size to an area segment of the roadway based on the roadway section and depth being constructed for the course being tested. The calculations in Example 1 show how this is performed. Table A1 has been provided to give you recommend lot lengths for standard lane widths at various depths. Lot length needs to be determined to the nearest 100 feet.

Example 1
Sample Computation for Lot Length

Using nominal compacted density of 2.05 tons/cy, and a 400 ton lot:

$$\text{Tons per linear foot} = \frac{\text{1.0 (foot) * width (feet) * depth (feet)) * 2.05 Tons/cy}}{27}$$

$$\text{Tons per linear Foot} = \frac{\text{1.0 ft * 12 ft * 0.15 ft * 2.05 tons}}{27} = \text{0.137 Tons per linear Foot}$$

$$\text{Lot length} = \frac{\text{400 Tons}}{\text{0.137 Tons per linear Foot}} = \text{2900 linear Feet}$$

Lane Width	Compacted Depth	Computed Lot Length	Recommended Lot Length
12 feet	0.12	3655	3700
	0.15	2924	2900
	0.20	2193	2200
	0.25	1754	1800
11 feet	0.12	3987	4000
	0.15	3189	3200
	0.20	2392	2400
	0.25	1913	1900

Hot Mix Asphalt Density Test Lot Length 400 Ton lot at 2.05 tons/cubic yard
Table A1

LOT length may also be determined based on Nominal Designated LOT sizes. To utilize this concept, compacted mix volumes equivalent to the designated mix quantity per LOT have been determined using the nominal compacted unit weight of Hot Mix asphalt. These volumes are then converted into Density LOT lengths using the typical lane width and specified compacted depth.

c. Determine the locations of the test (or sampling) sites by using values from the random number table to determine the coordinate location on the roadway. In the table, use the "X" values as decimal fractions of the total length of the lot; use the "Y" values as fractions of the width, customarily measured from the right edge of the pavement. The values in the table have been set so that no measurements are taken within 1.5 LF (0.45 m) of the edge of the pavement. Whenever a test location is determined to fall within such an area (i.e., bridge end, track crossing, or night joint) the test location should be moved ahead or back on stationing, as appropriate, by 25 LF (8 m).

d. In order to determine which "X" and "Y" values should be used, enter the table on a line chosen by chance. Recommended procedure is selection of a line based on the last two digits from the most recent standard count on the nuclear density gage. Subsequent "X" and "Y" values are then taken from the lines that follow. Based on the specified sampling frequency, 20 lots can be accommodated by one cycle through the table. Start each shift with a set of values determined by chance in order to obtain random selection.

e. Example 2 shows the calculations for determining the testing location for asphalt pavement density.

Example 2
Test Location Within the LOT
for Hot Mix Asphalt Density

For the lot: (12 ft. wide, 0.15 ft. deep, starting at station 168 + 75 with paving -progressing ahead on station), Lot length was previously determined as 2,900 LF. Using the last two digits of the standard count, as in the example, 2951, assume "X" and "Y" values from line (51) in random number table: X = 0.762, Y = 0.65.

For the first test:

Beginning station: 168 + 75

Sublot length increment: 580 * 0.762 = 442

Width offset: 12 * 0.65 = 7.8 ft. (from right edge)

Location is: station: (168+75) + 442 = 173 + 17, 7.8 ft. from right edge

For the Second test:

Beginning station: (168 + 75) + (580) = 174 + 55

Sublot length increment: 580 * 0.285 = 165

Width offset: 12 * 0.28 = 3.4 ft. (from right edge)

Location is: station: (174 + 55) + 165 = (176 + 20), 3.4 ft. from right edge

For the Third test:

Beginning station: (168 + 75) + 580 + 580 = 180 + 35

Sublot length increment: 580 * 0.347 = 201

Width offset: 12 * 0.87 = 10.4 ft. (from right edge)

Location is: station: (180 + 35) + 201 = (182 + 36), 10.4 ft. from right edge

Appendix B

HOT MIX ASPHALT DENSITY AND CHALLENGE CORES (Milepost)

a. Determine the LOT size and number of tests per LOT. The Standard specifications set the size of a density test lot for Hot Mix Asphalt Pavement to no greater than a single day's production or 400 tons, whichever is less, and require five tests per LOT. At the end of a day's production the final lot may be increased to a maximum of 600 tons.

b. Convert this LOT size to an area segment of the roadway based on the roadway section and depth being constructed for the course being tested. The calculations in Example 1 show how this is performed. Table A2 has been provided to give you recommend lot lengths for standard lane widths at various depths. Lot length needs to be determined to the nearest .01 of a mile.

Example 1
Sample Computation for Lot Length

Using nominal compacted density of 2.05 tons/cy, and a 400 ton lot:

$$\text{Tons per linear foot} = \frac{(1.0 \text{ (foot)} * \text{width (feet)} * \text{depth (feet)}) * 2.05 \text{ Tons/cy}}{27}$$

$$\text{Tons per linear Foot} = \frac{1.0 \text{ ft} * 12 \text{ ft} * 0.15 \text{ ft} * 2.05 \text{ tons}}{27} = 0.137 \text{ Tons per linear Foot.}$$

0.137 Tons per linear Foot * 5,280 ft = 723.36 Tons per mile

$$\text{Lot length} = \frac{400 \text{ Tons}}{723.36 \text{ Tons per mile}} = 0.55 \text{ linear miles}$$

Lane Width	Compacted Depth	Computed Lot Length	Recommended Lot Length
12 feet	0.12	0.69	0.69
	0.15	0.55	.55
	0.20	0.42	.42
	.25	0.33	.034
11 feet	0.12	0.76	0.76
	0.15	0.60	0.61
	0.20	0.45	0.46
	0.25	0.35	0.36

Hot Mix Asphalt Density Test Lot Length
400 Ton lot at 2.05 tons/cubic yard
Table A2

LOT length may also be determined based on Nominal Designated LOT sizes. To utilize this concept, compacted mix volumes equivalent to the designated mix quantity per LOT have been determined using the nominal compacted unit weight of Hot Mix asphalt. These volumes are then converted into Density LOT lengths using the typical lane width and specified compacted depth. The included tables present the values for LOT Lengths based on mileposts.

c. Determine the locations of the test (or sampling) sites by using values from the random number table to determine the coordinate location on the roadway. In the table, use the "X" values as decimal fractions of the total length of the lot; use the "Y" values as fractions of the width, customarily measured from the right edge of the pavement. The values in the table have been set so that no measurements are taken within 1.5 LF (0.45 m) of the edge of the pavement. Whenever a test location is determined to fall within such an area (i.e., bridge end, track crossing, or night joint) the test location should be moved ahead or back on milepost, as appropriate, by .01 mile.

d. In order to determine which "X" and "Y" values should be used, enter the table on a line chosen by chance. Recommended procedure is selection of a line based on the last two digits from the most recent standard count on the nuclear density gage. Subsequent "X" and "Y" values are then taken from the lines that follow. Based on the specified sampling frequency, 20 lots can be accommodated by one cycle through the table. Start each shift with a set of values determined by chance in order to obtain random selection.

e. Example 2 shows the calculations for determining the testing location for asphalt pavement density.

Example 2
Test Location Within the LOT
for Hot Mix Asphalt Density

For the lot: (12 ft. wide, 0.15 ft. deep, starting at Milepost 1.00 with paving ¬progressing ahead on Milepost), Lot length was previously determined as 0.55 miles. Using the last two digits of the standard count, as in the example, 2951, assume "X" and "Y" values from line (51) in random number table: X = 0.762, Y = 0.65.

For the first test:

Beginning Milepost: 1.00
Sublot length increment: .11 * 0.762 = .08
Width offset: 12 * 0.65 = 7.8 ft. (from right edge)
Location is: Milepost: (1.00) + .08 = 1.08, 7.8 ft. from right edge

For the Second test:

Beginning Milepost: (1.00) + (.11) = 1.11
Sublot length increment: .11 * 0.285 = .03
Width offset: 12 * 0.28 = 3.4 ft. (from right edge)
Location is: Milepost: (1.11) + .03 = (1.14), 3.4 ft. from right edge

For the Third test:

Beginning Milepost: (1.00) + .11 + .11 = 1.22
Sublot length increment: .11 * 0.347 = .04
Width offset: 12 * 0.87 = 10.4 ft. (from right edge)
Location is: Milepost: (1.22) + .04 = (1.26), 10.4 ft. from right edge

Washington State
Department of Transportation

WSDOT Test Method T 718

Method of test for Determining Stripping of Hot Mix Asphalt

1. SCOPE
   a. This test is used to determine the amount of stripping resulting from the effects of water saturation and accelerated water conditioning, with a freeze-thaw cycle of laboratory – compacted Hot Mix Asphalt.
   b. This test is the WSDOT equivalent to AASHTO T 283.
2. EQUIPMENT
   a. Water bath controlled at 140 ± 1.8°F.
   b. Vacuum container capable of holding a vacuum of approximately 26mm Hg and large enough to accommodate test specimens and volume of water as described in this procedure.
   c. Perforated platform to hold test samples 2 inches off the bottom of the vacuum container.
   d. Vacuum pump, vacuum system or water aspirator, for vacuum saturation of specimens.
   e. Air-bath freezer, maintained at 0 ± 5°F.
   f. Water bath maintained at 55 ± 1°F.
   g. Testing machine - A compression testing machine having a minimum capacity of 10000 lbf and capable of producing a uniform vertical movement of 0.065 inches per minute.
   h. Equipment for preparing and compacting specimens for WSDOT FOP for AASHTO T 312.
3. PREPARATION OF LABORATORY-MIXED, LABORATORY-COMPACTED SPECIMENS FOR MIX DESIGNS
   a. Mix specimens per WSDOT Test Method 726, at optimum asphalt binder content with appropriate grade and supplier of asphalt binder per the mix design to achieve approximately 4% air voids.
   b. Mix six specimens per asphalt binder supplier, two samples with 0% anti-strip additive and the other specimens with varying amounts of anti-strip additive (Note 1).

      Note 1: It is recommended that liquid anti-strip agents, added directly to the asphalt binder, be added at the level of ¼%, ½%, ¾% and 1% by weight of asphalt binder. Latex anti-strip agents must be added to the aggregate in a Saturated Surface Dry (SSD) condition at a level of 0.08%, 0.17%, 0.33% and 0.50% by weight of dry aggregate.

c. Condition and compact the specimens per WSDOT FOP for AASHTO T 312 sections 8.5 through 9.8.

PRECONDITIONING OF TEST SPECIMENS

a. Once the set of six specimens have been compacted and cooled to room temperature, set one of the specimens mixed with 0% anti-strip aside to be stored at room temperature, this will be the referee specimen.

b. Test remaining set of specimens per AASHTO T 166 Method A. Calculate the air void level of the specimen using mix design Theoretical Maximum Specific Gravity value.

c. Place the specimens in the vacuum container. The container must be filled with potable water at room temperature (77 ± 9°F) so that the specimens have at least 1 inch of water above their surface. Apply a vacuum for a short amount of time, suitable to saturate the specimens air voids between 60 and 80 percent.

d. Determine the mass of the saturated, surface-dry specimen after partial vacuum saturation per AASHTO T 166 Method A.

e. Calculate the volume of absorbed water (J) in cubic centimeters by use of the following equation:

$$J = B - A$$

Where:

J = volume of absorbed water, cubic centimeters.
B = mass of saturated, surface-dry specimen after partial vacuum.
A = mass of dry specimen in air.

f. Determine the degree of saturation (S) by comparing the volume of absorbed water (J) with the volume of air voids (Va) using the following equation.

$$S = \frac{100J}{Va}$$

Where:

S = Degree of saturation, percent.
Va = **Volume** of air voids

Determine the Volume of air voids using the following equation:

$$Va = \frac{Pa \times E}{100}$$

Where:

Pa = **Percent** of air voids
E = Volume of Specimen, cubic centimeters. (SSD wt. – wt. In water)

g. If the degree of saturation is between 60 and 80 percent then proceed. If the degree of saturation is less than 60 percent then repeat the procedure beginning with c above, using more vacuum and/or time. If the degree of saturation is more than 80 percent then the specimen has been damaged and must be discarded.

h. After saturation is achieved place each specimen in a plastic bag, seal the bag and place specimen in a freezer at a temperature of 0 ± 5°F for a minimum of 16 hours.

i. Remove specimens from the freezer, remove plastic bags and place them in a water bath maintained at 140 ± 2°F for 24 ± 1 hour. (Note 2)

Note 2: Some specimens become fragile after curing in the hot bath for 24 hours, as a precaution it may be necessary to place samples into suitable transfer dishes prior to placing them into the hot bath, to facilitate the movement of samples for the hot bath to the cold-water bath.

j. After 24 ± 1 hours in the 140 ± 2°F water bath, remove the specimens and place them into the cold water bath maintained at 55 ± 1°F. At this time the referee specimen shall be placed into the cold water bath with the conditioned specimens. Testing must begin within 2 hours ± 10 minutes after specimens have been placed into the cold water bath.

TESTING

a. After 2 hours ± 10 minutes in the cold water bath, remove and test one specimen at a time in the testing machine on the diametrical vertical plane. Apply the diametrical loading at a vertical deformation rate of 0.065 inches per minute. Record the maximum compressive load of each specimen.

b. Continue to load specimen until specimen can be easily broken open.

c. Remove specimen from machine, break specimen in half by hand for visual inspection. Record the visual condition of each specimen as to stripping action: none, slight, moderate, or severe.

d. Determine the Tensile Strength Ratio (TSR) of each specimen by comparing the load needed to break the testing specimen to the load needed to break the referee specimen, using the following equation:

$$TSR = \left(\frac{S_1}{S_2}\right) \times 100$$

Where:

S_1 = tensile strength of the conditioned specimen
S_2 = tensile strength of the unconditioned specimen

VISIUAL CONDITION DEFINITIONS

NONE: The specimen condition is solid with no evidence of asphalt binder withdrawing from aggregate. After the specimen has air-dried, the appearance is black.

SLIGHT: The specimen condition is solid to slightly soft with evidence of the asphalt binder beginning to withdraw from edges and surfaces of the aggregates. After the specimen has air-dried, the appearance remains black.

MODERATE: The specimen condition is soft, easily broken in half, with partial to completely exposed aggregates. After the specimen has air-dried, the appearance is slightly gray.

SEVERE: The specimen condition is soft to falling apart with the majority of coarse aggregate completely exposed and asphalt binder almost nonexistent. After the specimen has air-dried, the appearance is gray.

REPORT

The report shall include the following: Visually estimated moisture damage (stripping) and Tensile Strength Ratio (TSR) of the specimens.

WSDOT SOP 729

Determination of Moving Theoretical Maximum Density and Calculation of In-Place Density of Bituminous Mixes Using the Nuclear Moisture-Density Gauge FOP for WAQTC TM 8

1. Number and Locations of Nuclear Tests

   a. Nuclear gauge tests shall be performed per the Standard Specification or Contract Special Provisions. The locations will be picked at random by WSDOT Test Method No. 716.

2. Theoretical Maximum Density determination FOR PAVEMENT COMPACTION CONTROL

   2.1 Responsibility of the Tester at the HMA plant

   a. Theoretical Maximum Density (TMD) is to be determined per WSDOT FOP for AASHTO T 209.

   b. On the initial day of production of a new Job Mix Formula (JMF), two determinations shall be made to establish an initial average value. The samples shall not be from the same truck. Average the two Theoretical Maximum Densities and report the result to the Moisture Density Gauge Operator. The Theoretical Maximum Density value from the Mix Design shall not be included in the average. If the two Theoretical Maximum Densities determined on the initial day do not agree within 3.0 lb./ft.^{3} (48 kg/m^3), a third determination shall be made. The initial average density shall be based on the two closest results.

   c. For Non Volumetric projects, a TMD test shall be taken with the first mix sample of each production shift. For Volumetric projects, a TMD test shall be taken with each mix sample. The moving average is defined as the average of the last five Theoretical Maximum Density (TMD) values for the HMA being placed. Until five TMD values have been determined, the moving average will consist of all previous TMD values plus the first TMD value for the current production shift. When five TMD values have been determined, the moving average for each shift will include the last four TMD values plus the first TMD value for the current paving shift. This new moving average value will be used for the entire paving shift.

d. Each TMD shall be compared with the previously computed moving average. If a TMD deviates from the moving average by more than 3.0 lb./ft.3 (± 48 kg/m3), a second test shall be made on another portion of the same sample. If the second TMD agrees within 3.0 lb./ft.3 (± 48 kg/m3) of the moving average then the first TMD will be discarded and the second TMD will be included in the moving average. If the second TMD is not within 3.0 lb./ft.3 (± 48 kg/m3) of the moving average but is within 3.0 lb./ft.3 (± 48 kg/m3) of the first TMD, a new moving average will be initiated, discarding all previous results. The new moving average will be sent to the Moisture Density Gauge operator and will replace the current moving average.

e. A moving average will be sent to the Moisture Density Gauge operator once per production shift, unless two tests during a shift are not within 3.0 lb./ft.3 (± 48 kg/m3), then a new moving average will be calculated in accordance with "e" of this procedure and sent to the Moisture Density Gauge operator as the new moving average for the shift. The Moisture Density Gauge Operator will continue to use the previous moving average until a new moving average is available.

2.2 Responsibility of the Density Operator

a. The Moisture Density Gauge Operator will receive a new Theoretical Maximum Density each day that production requires a mix test.

b. The Operator will continue to use the previous moving average until a new moving average is received from the tester at the HMA plant.

3. Acceptance

a. For acceptable compaction, nuclear gauge test results for the control lot shall be determined by WAQTC FOP for TM8.

b. The percent compaction of the in-place nuclear gauge wet density reading is calculated as follows.

$$\text{Percent Compaction} = \frac{(\text{WD})\ (\text{CF})}{\text{Average Theoretical Maximum Density}} \times (100)$$

WD = nuclear gauge wet density reading in accordance with TM8.

CF = gauge correlation factor.

4. REPORT

Report the results on the WDOT Form 350-092 and 350-157

Report the percent compaction to the nearest tenth of a percent (0.1 percent).

Washington State
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WSDOT SOP 730

Correlation of Nuclear Gauge Densities with Hot Mix Asphalt (HMA) Cores

1. Gauge-core correlation shall be required for statistical evaluation of degree of asphalt compaction.
   a. For each combination of gauge and job mix formula.
   b. For direct transmission and for back scatter modes (when used).
   c. If gauge is recalibrated.
2. A new gauge correlation is not required.
   a. For different contracts if JMF and gauge are the same.
   b. For a change in bases (i.e., surfacing to overlay).
   c. When the job mix formula has been adjusted in accordance with Section 9-03.8(7)A of the *Standard Specifications*.
3. Gauge correlation is based on 10 density determinations and 10 cores taken at corresponding locations. Gauge densities shall be determined in accordance with WSDOT FOP for WAQTC TM 8. Cores should be taken no later than the day following paving and before traffic has been allowed on roadway. The sites for correlation cores do not have to be record density locations and therefore consideration should be given to selecting sites out of the travel way.

   Note1: If a core becomes damaged, it may be eliminated from the average.

   Note2: Cores may be taken sooner than the day after paving by cooling the pavement to allow for hardening of the HMA to prevent damage to the core when taking the sample. Water, ice, or even dry-ice would be expedient means to cool the pavement. Nitrogen gas or CO2 uses as replacement drilling fluids may also be involved.
4. Obtain a pavement core from each of the test sites in accordance with WSDOT SOP 734. The core shall be taken in ~~between~~ the ~~two~~ nuclear gauge footprint~~s~~. If direct transmission was used, locate the core at least 1 in. (25 mm) away from the edge of the drive pin hole.
5. Core densities shall be determined in conformance with AASHTO T 166 Bulk Specific Gravity of Compacted Bituminous Mixtures Using Saturated Surface-Dry Specimens.
6. Correlation factor shall be determined to 0.001 using Standard Form 350-112: Correlation Nuclear Gauge to Core Density, or other comparable forms.

Washington State Department of Transportation

WSDOT SOP 731

Method for Determining Volumetric Properties of Hot Mix Asphalt Class Superpave

1. SCOPE

   This procedure covers the determination of volumetric properties of Asphalt Concrete Pavement Class Superpave i.e. Air Voids (Va), Voids in Mineral Aggregate (VMA), Voids Filled with Asphalt (VFA), and Dust to Binder Ratio ($P_{\#200}/P_{be}$).

2. REFERENCES

   a. T 329, WSDOT FOP for AASHTO Moisture Content of Asphalt (HMA) by Oven Method

   b. T 27/11, WSDOT FOP for WAQTC/AASHTO Sieve Analysis of Fine and Coarse Aggregates

   c. T 166, WSDOT FOP for AASHTO Bulk Specific Gravity of Compacted Hot Mix Asphalt Using Saturated Surface-Dry Specimens

   d. T 168, WSDOT FOP for WAQTC/AASHTO Sampling of Hot Mix Asphalt Paving Mixtures

   e. T 209, WSDOT FOP for AASHTO Theoretical Maximum Specific Gravity and Density of Hot Mix Asphalt Paving Mixtures

   f. T 308, WSDOT FOP for AASHTO Determining the Asphalt Binder Content of Hot Mix Asphalt (HMA) by the Ignition Method

   g. T 312, WSDOT FOP for AASHTO Preparing Hot Mix Asphalt (HMA) Specimens by Means of the Superpave Gyratory Compactor

   h. T 712, WSDOT Test Method Standard Method of Reducing Hot Mix Asphalt Paving Mixtures

3. CALIBRATION OF COMPACTOR

   a. The gyratory compactor will be calibrated in accordance with WSDOT VP-58 and according to the manufacturer's established calibration procedure. Anytime the gyratory compactor is moved to a new testing site a new calibration is required in accordance with WSDOT VP-58.

4. TEST SAMPLES

   a. All test samples shall be obtained per WSDOT FOP for WAQTC/AASHTO T 168, and reduced in accordance with WSDOT Test Method T 712. It is recommended that the gyratory test sample be the first sample acquired in order to minimize heat loss.

b. The size of the gyratory sample shall be such that it will produce a compacted specimen 115.0 ± 5.0 mm in height. Generally, the mix design verification report from the State materials Laboratory initial starting mass is adequate.

c. Place the gyratory sample in an oven set no more than 25°F above the compaction temperature (Note 1) as soon as possible to reduce sample cooling. The gyratory test is temperature sensitive. The sample should ~~only~~ be heated five degrees above ~~until it achieves~~ the compaction temperature as shown on the mix design verification report.

Note 1: ~~The compaction temperature for each mix design can be found on the mix design report.~~ Any change in compaction temperature must be confirmed by the temperature viscosity chart provided by the asphalt supplier, which can be obtained from the Paving Contractor.

5. PROCEDURE

a. Place a compaction mold, base plate, and top plate (if required), in an oven set at no more than 25°F above compaction temperature (Note 2) for a minimum of 60 minutes prior to the estimated beginning of compaction. Subsequent uses of a conditioned mold will require 5 minutes reheating.

Note 2: Never heat any gyratory compactor mold in excess of 350°F.

b. Place a thermometer into the center of the mix, do not stir the mixture. (Note 3) Compact the sample immediately upon achieving compaction temperature in accordance with step 4 (c).

Note 3: While the gyratory test sample is heating it is beneficial to prepare and/or run the other tests as times permits.

c. Perform the sample compaction in accordance with WSDOT FOP for AASHTO T 312 Section 9.

d. Determine theoretical maximum density per WSDOT FOP for AASHTO T 209.

e. Determine asphalt content and gradation per WSDOT FOP for AASHTO T 308 and WSDOT FOP for WAQTC/AASHTO T 27/11.

f. Determine moisture content per WSDOT FOP for AASHTO T 329.

g. Allow the gyratory compacted specimen to cool at room temperature for 15 to 24 hours. Determine the Bulk Specific Gravity (Gmb) of the specimen in accordance with WSDOT FOP for AASHTO T 166 Method A.

Note 4: For repeatability between operators the challenge sample should be cooled for the same amount of time at room temperature as the original specimen. When sending challenge samples to the Region or State Laboratory, note the time the original sample was cooled at room temperature in the remarks section of the transmittal.

6. VOLUMETRIC CALCULATIONS

CALCULATIONS

a. Calculate $\%G_{mm}$ @N_{design} as follows:

$$\%G_{mm} @ N_{design} = \frac{G_{mb}}{G_{mm}} \times 100$$

Example:

$$\%G_{mm} @ N_{design} = \frac{2.383}{2.493} \times 100 = 95.6\%$$

Where:

$\%G_{mm}$@N_{design} = % theoretical maximum specific gravity @ N_{design}
G_{mb} = bulk specific gravity of the compacted specimen
G_{mm} = maximum specific gravity of the paving mixture
N_{design} = number of design gyrations

b. Calculate $\%G_{mm}$ @N_{ini} as follows:

$$\%G_{mm} @ N_{ini} = 100 \times \left(\frac{G_{mb} \times h_d}{G_{mm} \times h_i} \right)$$

Example:

$$\%G_{mm} @ N_{ini} = 100 \times \left(\frac{2.383 \times 110.0}{2.493 \times 123.1} \right) = 85.4\%$$

Where:

$\%G_{mm}$@N_{ini} = % theoretical maximum specific gravity @ $N_{initial}$
h_d = height of specimen at design gyration level
h_i = height of specimen at initial design gyration level
$N_{initial}$ = number of initial gyrations

c. Calculate Air Voids (V_a) as follow:

$$V_a = 100 \times \left(1 - \left(\frac{G_{mb}}{G_{mm}} \right) \right)$$

Example:

$$V_a = 100 \times \left(1 - \left(\frac{2.383}{2.493} \right) \right) = 4.4\%$$

Where:

V_a = percent air voids

d. Calculate Voids in Mineral Aggregate (VMA) as follows:

$$VMA = 100 - \left(\frac{G_{mb} \times P_s}{G_{sb}}\right)$$

Example:

$$VMA = 100 - \left(\frac{(2.383 \times 94.8)}{2.630}\right) = 14.1\%$$

Where:

P_s = percent of aggregate in the mixture (100-P_b)

Example : 100% mix – 5.2% asphalt = 94.8% aggregate

G_{sb} = bulk specific gravity of the combined aggregate

VMA = Voids in Mineral Aggregate, percent

e. Calculate Voids Filled with Asphalt (VFA) as follows:

$$VFA = 100 \times \left(\frac{VMA - V_a}{VMA}\right)$$

Example:

$$VFA = 100 \times \left(\frac{14.1 - 4.4}{14.1}\right) = 68.8\%$$

Where:

VFA = Voids Filled with Asphalt, percent

f. Calculate Gravity Stone Effective (G_{se}) as follows:

$$G_{se} = \frac{100 - P_b}{\left(\frac{100}{G_{mm}} - \frac{P_b}{G_b}\right)}$$

Example:

$$G_{se} = \frac{100 - 5.2}{\left(\frac{100}{2.493} - \frac{5.2}{1.025}\right)} = 2.706$$

Where:

G_{se} = Gravity Stone Effective (specific gravity of aggregates, excluding voids permeable to asphalt)

P_b = percent of binder

G_b = Gravity binder

Note 4: G_b is the specific gravity of the asphalt binder. It is imperative that current G_b is used in the volumetric calculations. Any changes in the binder specific gravity must be confirmed by the temperature viscosity curve provided by the asphalt supplier, which can be obtained from the paving Contractor.

g. Calculate Percent Binder Effective (P_{be}) as follows:

$$P_{be} = P_b - \left(\frac{(Ps \times Gb)(Gse - Gsb)}{(Gse \times Gsb)} \right)$$

Examples:

$$P_{be} = 5.2 - \left(\frac{(94.8 \times 1.025)(2.706 - 2.630)}{(2.706 \times 2.630)} \right)$$

Where:

P_{be} = percent binder effective, the percent by mass of effective asphalt content minus the quantity of binder lost by absorption into the aggregate particles.
P_s = percent of aggregate in the mixture
G_b = Gravity binder
G_{se} = effective specific gravity of the aggregate
G_{sb} = bulk specific gravity of the combined aggregate
P_b = percent of binder

h. Calculate dust-to-binder ratio (P_{200}/P_{be}) as follows:

$$P_{200}/P_{be} = P_{200} \div P_{be}$$

Example: $5.0 \div 3.6 = 1.4$

Where:

P_{200}/P_{be} = dust-to-binder ratio
P_{200} = percent of aggregate passing the No. 200 sieve

7. REPORT

Report asphalt content, gradation, and moisture content on WSDOT Form 350-560EF, and report volumetric properties on WSDOT Form 350-162 or other report approved by the State Materials Engineer.

Washington State
Department of Transportation

WSDOT SOP 732[1]

Volumetric Design for Hot-Mix Asphalt (HMA)

1. SCOPE

   1.1. This standard for mix design evaluation uses aggregate and mixture properties to produce a hot-mix asphalt (HMA) job-mix formula. The mix design is based on the volumetric properties of the HMA in terms of the air voids (V_a), voids in the mineral aggregate (VMA), and voids filled with asphalt (VFA).

   1.3. This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of the user of this procedure to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Referenced Documents

   2.1. AASHTO Standards:
   - M 320, Performance-Graded Asphalt Binder
   - M 323, Superpave Volumetric Mix Design
   - R 30, Mixture Conditioning of Hot-Mix Asphalt (HMA)
   - R 35, Superpave Volumetric Design for Hot-Mix Asphalt (HMA)
   - T 2, Sampling of Aggregates
   - T 11, Materials Finer Than 75-µm (No. 200) Sieve in Mineral Aggregates by Washing
   - T 27, Sieve Analysis of Fine and Coarse Aggregates
   - T 84, Specific Gravity and Absorption of Fine Aggregate
   - T 85, Specific Gravity and Absorption of Coarse Aggregate
   - T 100, Specific Gravity of Soils
   - T 166, Bulk Specific Gravity of Compacted Hot Mix Asphalt Using Saturated Surface-Dry Specimens
   - T 209, Theoretical Maximum Specific Gravity and Density of Hot Mix Asphalt Paving Mixtures
   - T 228, Specific Gravity of Semi-Solid Bituminous Materials
   - T 248, Reducing Samples of Aggregate to Testing Size
   - T 275, Bulk Specific Gravity of Compacted Bituminous Mixtures Using Paraffin-Coated Specimens
   - T 283, Resistance of Compacted Asphalt Mixture to Moisture-Induced Damage
   - T 304, Uncompacted Void Content of Fine Aggregate
   - T 312, Preparing and Determining the Density of the Hot-Mix Asphalt (HMA) Specimens by Means of the Superpave Gyratory Compactor

[1] This Standard Operating procedure is based on AASHTO T 323-04

2.2. Asphalt Institute:

- MS-2, Mix Design Methods for Asphalt Concrete and Other Hot-Mix Types

2.3. ASTM Standards:

- D4791 Flat Particles, Elongated Particles, or Flat and Elongated Particles in Coarse Aggregate

2.4. WSDOT Standards:

- M 41-01, Construction Manual
- M 41-10, Standard Specifications for Road, Bridge, and Municipal Construction (Std. Specs.)
- M 46-01, Materials Manual
- SOP 731 Method for Determining Volumetric Properties of Hot-Mix Asphalt (HMA)
- T 2, WSDOT FOP for AASHTO for Standard Practice for Sampling Aggregate
- T 27/11, WSDOT FOP for WAQTC/AASHTO for Sieve Analysis of Fine and Coarse Aggregates
- T 113, Method of Test for Determination of Degradation Value
- T 166, WSDOT FOP for AASHTO for Bulk Specific Gravity of Compacted Hot Mix Asphalt Using Saturated Surface-Dry Specimens
- T 176, WSDOT FOP for AASHTO for Plastic Fines in Graded Aggregates and Soils by Use of the Sand Equivalent Test
- T 209, WSDOT FOP for AASHTO for Method of Test for Maximum Specific Gravity of Hot Mix Asphalt Paving Mixtures "Rice Density"
- T 248, WSDOT FOP for AASHTO for Reducing Samples of Aggregates to Testing Size
- T 304, WSDOT Test Method for AASHTO T 304 Uncompacted Void Content of Fine Aggregate
- T 312, WSDOT FOP for AASHTO for Preparing and Determining the Density of Hot-Mix Asphalt (HMA) Specimens by Means of the Superpave Gyratory Compactor
- T 335 WSDOT FOP for AASHTO T 335 Determining the Percentage of Fracture in Coarse Aggregate
- T 702, Method of Preparation of Test Specimens of Hot Mix Asphalt by Means of California Kneading Compactor
- T 718, Method of Test for Determining Stripping of Hot Mix Asphalt
- T 724, Method of Preparation of Aggregate for HMA Mix Designs
- T 726 Mixing Procedure for Hot-Mix Asphalt (HMA)
- D 4791, WSDOT FOP for ASTM D4791 Standard Test Method for Flat Particles, Elongated Particles, or Flat and Elongated Particles in Coarse Aggregate

3. Terminology

3.1. *HMA – hot-mix asphalt*

3.2. *design ESALs*—design equivalent (80kN) single-axle loads

3.2.1. *Discussion*—design ESALs are the anticipated project traffic level expected on the design lane over a 15-year period. For pavements designed for more or less than 15 years, determine the design ESALs for 15 years when using this standard.

3.3. *air voids* (V_a)—the total volume of the small pockets of air between the coated aggregate particles throughout a compacted paving mixture, expressed as a percent of the bulk volume of the compacted paving mixture (Note 1).

Note 1: Term defined in Asphalt Institute Manual MS-2, *Mix Design Methods for Asphalt Concrete and Other Hot-Mix Types*.

3.4. *voids in the mineral aggregate* (VMA)—the volume of the intergranular void space between the aggregate particles of a compacted paving mixture that includes the air voids (V_a), and the effective binder content(P_{be}), expressed as a percent of the total volume of the specimen (Note 1).

3.5. *absorbed binder volume* (V_{ba})—the volume of binder absorbed into the aggregate (equal to the difference in aggregate volume when calculated with the bulk specific gravity and effective specific gravity).

3.6. *binder content* (P_b)—The percent by mass of binder in the total mixture including binder and aggregate.

3.7. *effective binder volume* (V_{be})—The volume of binder which is not absorbed into the aggregate.

3.8. *voids filled with asphalt* (VFA)—The percentage of the voids in the mineral aggregate (VMA) filled with binder (the effective binder volume divided by the VMA).

3.9. Dust/Asphalt Ratio (P_{200}/P_{be})—By mass, ratio between percent passing the No. 200 (0.075-mm) sieve (P_{200}) and the effective binder content (P_{be}).

3.10. *nominal maximum aggregate size*—For aggregate, the nominal maximum size, (NMS) is the largest standard sieve opening listed in the applicable specification, upon which any material is permitted to be retained. For concrete aggregate, NMS is the smallest standard sieve opening through which the entire amount of aggregate is permitted to pass.

WSDOT Note 1: For an aggregate specification having a generally unrestrictive gradation (i.e. wide range of permissible upper sizes), where the source consistently fully passes a screen substantially smaller than the maximum specified size, the nominal maximum size, for the purpose of defining sampling and test specimen size requirements may be adjusted to the screen, found by experience to retain no more than 5% of the materials.

3.11. *maximum aggregate size*—One size larger than the nominal maximum aggregate size (Note 2).

Note 2: The definitions given in sections 3.10 and 3.11 apply to Superpave mixes only and differ from the definitions published in other AASHTO standards.

3.12. *reclaimed asphalt pavement* (RAP)—Removed and/or processed pavement materials containing asphalt binder and aggregate.

3.13. $N_{initial}$, N_{design}, $N_{maximum}$—the number of gyrations defined in WSDOT contract provisions.

3.14. *Effective Asphalt Content,* P_{be}- the total asphalt content of a paving mixture minus the portion of asphalt that is lost by absorption into the aggregate particles (Note 1).

4. Summary of the Practice

4.1. *Materials Selection*—Binder and aggregate and RAP stockpiles are selected that meet the environmental and traffic requirements applicable to the paving project. The bulk specific gravity of all aggregates proposed for blending and the specific gravity of the binder are determined.

Note 3: If RAP is used, the bulk specific gravity of the RAP aggregate may be estimated by determining the theoretical maximum specific gravity (G_{mm}) of the RAP mixture and using an assumed asphalt absorption for the RAP aggregate to back-calculate the RAP aggregate bulk specific gravity, if the absorption can be estimated with confidence. The RAP aggregate effective specific gravity may be used in lieu of the bulk specific gravity at the discretion of the Agency. The use of the effective specific gravity may introduce an error into the combined aggregate bulk specific gravity and subsequent VMA calculations. The Agency may choose to specify adjustments to the VMA requirements to account for this error based on experience with their local aggregates.

4.2. *Design Aggregate Structure*—It is recommended at least three trial aggregate blend gradations from selected aggregate stockpiles are blended. For each trial gradation, an initial trial binder content is determined, and at least two specimens are compacted in accordance with WSDOT FOP for AASHTO T 312. A design aggregate structure and an estimated design binder content are selected on the basis of satisfactory conformance of a trial gradation meeting the requirements given in Section 9-03.8(2) of the Standard Specifications for Road, Bridge, and Municipal Construction (*Standard Specifications*) for V_a, VMA, VFA, Dust/Asphalt Ratio at N_{design}, and relative density at N_{intial}.

Note 4: Previous Superpave mix design experience with specific aggregate blends may eliminate the need for three trial blends.

4.3. *Design Binder Content Selection*—Replicate specimens are compacted in accordance with WSDOT FOP for AASHTO T 312 at the estimated design binder content and at the estimated design binder content ±0.5 percent percent. The design binder content is selected on the basis of satisfactory conformance with the requirements of Section 9-03.8(2) of the *Standard Specifications* for V_a, VMA, VFA, and Dust/Asphalt Ratio (P_{200}/P_{be}) at N_{des}, and the relative density at N_{ini} and N_{max}. For WSDOT projects, the design binder content selection is determined by the Contractor and is verified by the WSDOT.

4.4. *Evaluating Moisture Susceptibility*—The moisture susceptibility of the design aggregate structure is evaluated at the design binder content: compacted to approximately 4.0 percent air voids in accordance with WSDOT T 702, and evaluated according to WSDOT T 718. The design shall meet the tensile strength ratio requirement of WSDOT T 718. The WSDOT State Materials Laboratory will evaluate the HMA for moisture susceptibility.

5. Significance and Use

5.1. The procedure described in this practice is used to produce HMA which satisfies Superpave HMA volumetric mix design requirements.

6. Preparing Aggregate Trial Blend Gradations

6.1. The asphalt binder grade will be indicated in WSDOT Contract Special Provisions.

6.2. Determine the specific gravity of the binder according to T 228.

6.3. Obtain samples of aggregates proposed to be used for the project from the aggregate stockpiles in accordance with WSDOT FOP for AASHTO T 2.

Note 5: Each stockpile usually contains a given size of an aggregate fraction. Most projects employ three to five stockpiles to generate a combined gradation conforming to the job-mix formula and Section 9-03.8(6) of the *Standard Specifications*.

6.4. Reduce the samples of aggregate fractions according to WSDOT FOP for AASHTO T 248 to samples of the size specified in WAQTC FOP for AASHTO T 27/T 11.

6.5. Wash and grade each aggregate sample according to WAQTC FOP for AASHTO T 27/T 11.

6.6. Determine the bulk and apparent specific gravity for each coarse and fine aggregate fraction in accordance with T 85 and T 84, respectively, and determine the specific gravity of the mineral filler in accordance with T 100. WSDOT requires specific gravity determinations to be reported to an accuracy of 0.001.

6.7. Blend the aggregate fractions using Equation 1:

$$P = Aa + Bb + Cc, \text{ etc.} \tag{1}$$

where:

P	=	percentage of material passing a given sieve for the combined aggregates *A, B, C, etc.*;
A, B, C, etc.	=	percentage of material passing a given sieve for aggregates *A, B, C, etc.*; and
a, b, c, etc.	=	proportions of aggregates *A, B, C, etc*. used in the combination, and where the total = 1.00.

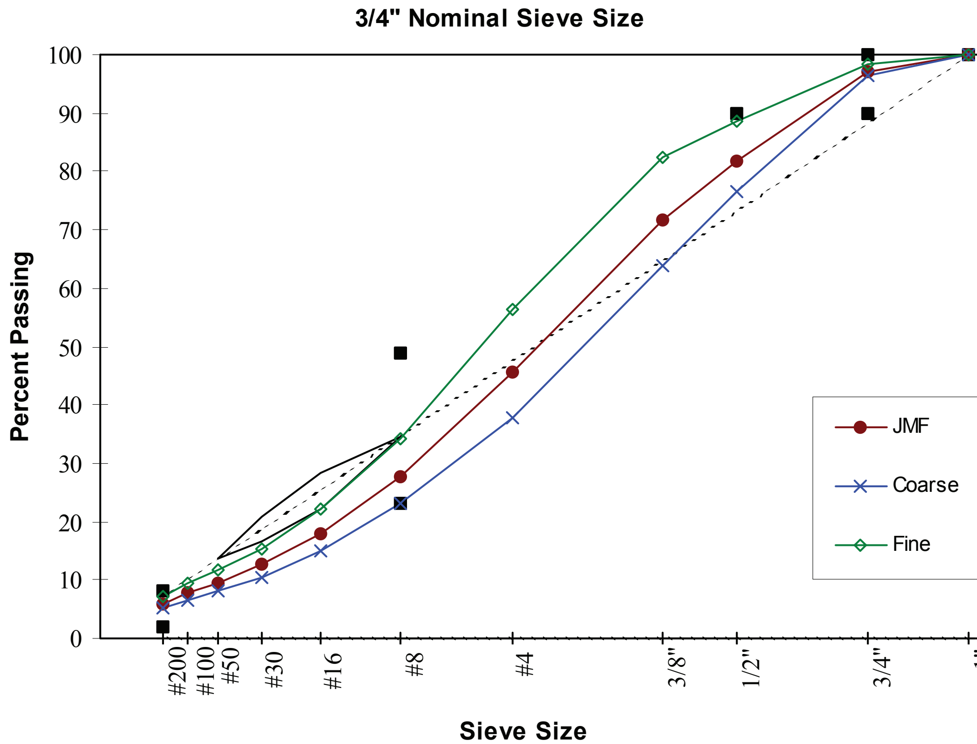
6.8. Prepare a minimum of three trial aggregate blend gradations; plot the gradation of each trial blend on a 0.45-power gradation analysis chart, and confirm that each trial blend meets the Aggregate Gradation Control Points in Section 9-03.8(6) of the *Standard Specifications* Gradation control is based on four control sieve sizes: the sieve for the maximum aggregate size, the sieve for the nominal maximum aggregate size, the No. 4 or No. 8 (4.75- or 2.36-mm) sieve, and the No. 200 (0.075-mm) sieve. For WSDOT projects, gradation shall be determined by the following sieves as defined in table W1T An example of three acceptable trial blends in the form of a gradation plot is given in Figure 1.

Sieves Required for Gradation Determination				
Sieve Size	⅜ In.	½ In.	¾ In.	1 In.
1½”				X
1”			X	X
¾”		X	X	X
½”	X	X	X	X
⅜”	X	X	X	X
No. 4	X	X	X	X
No. 8	X	X	X	X
No. 16	X	X	X	X
No. 30	X	X	X	X
No. 50	X	X	X	X
No. 100	X	X	X	X
No. 200	X	X	X	X
X = indicates sieve is required for gradation determination				

Table W1T

6.9. Obtain a test specimen from each of the trial blends according to WSDOT FOP for AASHTO T 248, and conduct the quality tests specified in Section 9-03.8(2) subsections 1, 2, 3, and 4 of the *Standard Specifications* to confirm that the aggregate in the trial blends meets the minimum quality requirements specified in Section 9-03.8(2) of the *Standard Specifications*.

Note 6: The designer has an option of performing the quality tests on each stockpile instead of the trial aggregate blend. The test results from each stockpile can be used to estimate the results for a given combination of materials.



Evaluation of the Gradations of Three Trial Blends (Example)
Figure 1

7. Determining an Initial Trial Binder Content for Each Trial Aggregate Gradation

   7.1. Designers can either use their experience with the materials or the procedure given in Appendix A1 to determine an initial trial binder content for each trial aggregate blend gradation.

   Note 7: When using RAP, the initial trial asphalt content should be reduced by an amount equal to that provided by the RAP.

8. Compacting Specimens of Each Trial Gradation

   8.1. Prepare replicate mixtures (Note 8) at the initial trial binder content for each of the chosen trial aggregate trial blend gradations. From Table 1, determine the number of gyrations based on the design ESALs for the project. On WSDOT projects the ESAL level will be indicated in the Contract Special Provisions.

   Note 8: At least two replicate specimens are required, but three or more may be prepared if desired. Generally, 4500 to 4700 g of aggregate is sufficient for each compacted specimen with a height of 110 to 120 mm for aggregates with combined bulk specific gravities of 2.550 to 2.700, respectively.

   8.2. Condition the mixtures according to R 30, and compact the specimens to N_{design} gyrations in accordance with WSDOT FOP for AASHTO T 312. Record the specimen height to the nearest 0.1 mm after each revolution.

8.3. Determine the bulk specific gravity (G_{mb}) of each of the compacted specimens in accordance with WSDOT FOP for AASHTO T 166 or T 275 as appropriate. The bulk specific gravity results of the replicate specimens shall not differ by more than 0.020.

Design ESALs[a] (million)	Compaction Parameters			Typical Roadway Application[b]
	$N_{initial}$	N_{design}	N_{max}	
< 0.3	6	50	75	Applications include roadways with very light traffic volumes such as local roads, county roads, and city streets where truck traffic is prohibited or at a very minimal level. Traffic on these roadways would be considered local in nature, not regional, intrastate, or interstate. Special purpose roadways serving recreational sites or areas may also be applicable to this level.
0.3 to < 3	7	75	115	Applications include many collector roads or access streets. Medium-trafficked city streets and the majority of county roadways may be applicable to this level.
3 to < 30	8	100	160	Applications include many two-lane, multilane, divided, and partially or completely controlled access roadways. Among these are medium to highly trafficked city streets, many state routes, U.S. highways, and some rural Interstates.
≥ 30	9	125	205	Applications include the vast majority of the U.S. Interstate system, both rural and urban in nature. Special applications such as truck-weighing stations or truck-climbing lanes on two-lane roadways may also be applicable to this level.

[a] The anticipated project traffic level expected on the design lane over a 15-year period. Regardless of the actual design life of the roadway, determine the design ESALs for 15 years.

[b] As defined by *A Policy on Geometric Design of Highways and Streets, 2001*, AASHTO.

Superpave Gyratory Compaction Effort
Table 1

8.4. Determine the theoretical maximum specific gravity (G_{mm}) according to WSDOT FOP for AASHTO T 209 of separate samples representing each of these combinations that have been mixed and conditioned to the same extent as the compacted specimens.

Note 11: The maximum specific gravity for each trial mixture shall be based on the average of at least two tests. The maximum specific gravity results of the replicate specimens shall not differ by more than 0.011.

9. Evaluating Compacted Trial Mixtures

9.1. Determine the volumetric requirements for the trial mixtures in accordance with Section 9-03.8(2) of the *Standard Specifications*.

9.2. Calculate V_a and VMA at N_{design} for each trial mixture using equations 2 and 3:

$$V_a = 100 \times \left(1 - \left(\frac{G_{mb}}{G_{mm}}\right)\right) \tag{2}$$

$$VMA = 100 - \left(\frac{G_{mb}P_s}{G_{sb}}\right) \tag{3}$$

where:

G_{mb} = bulk specific gravity of the extruded specimen;
G_{mm} = theoretical maximum specific gravity of the mixture;
P_s = percent of aggregate in the mixture $(100\text{-}P_b)$
G_{sb} = bulk specific gravity of the combined aggregate.

Note 12: Although the initial trial binder content was estimated for a design air void content of 4.0 percent, the actual air void content of the compacted specimen is unlikely to be exactly 4.0 percent. Therefore, the change in binder content needed to obtain a 4.0 percent air void content, and the change in VMA caused by this change in binder content, is estimated. These calculations permit the evaluation of VMA and VFA of each trial aggregate gradation at the same design air void content, 4.0 percent.

9.3. Estimate the volumetric properties at 4.0 percent air voids for each compacted specimen. On WSDOT projects theV_a, VMA, VFA criteria, and gyration level, will be specified in the Contract Provisions.

9.3.1. Determine the difference in average air void content at N_{design} (ΔV_a) of each aggregate trial blend from the design level of 4.0 percent using Equation 4:

$$\Delta Va = 4.0 - Va \tag{4}$$

where:

V_a = air void content of the aggregate trial blend at N_{design} gyrations.

9.3.2. Estimate the change in binder content (ΔP_b) needed to change the air void content to 4.0 percent using Equation 5:

$$\Delta P_b = -0.4(\Delta V_a) \tag{5}$$

9.3.3. Estimate the change in VMA (ΔVMA) caused by the change in the air void content (ΔV_a) determined in Section 9.3.1 for each trial aggregate blend gradation, using Equations 6 or 7.

$$\Delta VMA = 0.2(\Delta V_a) \text{ if } V_a > 4.0 \tag{6}$$

$$\Delta VMA = 0.1(\Delta V_a) \text{ if } V_a > 4.0 \tag{7}$$

Note 13: A change in binder content affects the VMA through a change in the bulk specific gravity of the compacted specimen (G_{mb}).

9.3.4. Calculate the VMA for each aggregate trial blend at N_{design} gyrations and 4.0 percent air voids using Equation 8:

$$VMA_{design} = VMA_{trial} + \Delta VMA \tag{8}$$

where:

VMA$_{design}$ = VMA estimated at a design air void content of 4.0 percent; and

VMA$_{trial}$ = VMA determined at the initial trial binder content.

9.3.5. Using the values of ΔV_a determined in Section 9.3.1 and Equation 9, estimate the relative density of each specimen at N_{initial} when the design air void content is adjusted to 4.0 percent at N_{design}:

$$\%G_{mm_{\text{initial}}} = 100 \times \left(\frac{G_{mb} h_d}{G_{mm} h_i}\right) - \Delta V_a \tag{9}$$

where:

$\%G_{mm\ \text{initial}}$ = relative density at N_{initial} gyrations at the adjusted design binder content;

h_d = height of the specimen after N_{design} gyrations, from the Superpave gyratory compactor, mm; and

h_i = height of the specimen after N_{initial} gyrations, from the Superpave gyratory compactor, *mm*.

9.3.6. Estimate the percent of effective binder (P_{be}) and calculate the Dust/Asphalt Ratio (P_{200}/P_{be}) for each trial blend using Equations 10 and 11:

$$P_{be_{est}} = -(P_s \times G_b)\frac{(G_{se} - G_{sb})}{(G_{se} \times G_{sb})} + P_{b_{est}} \tag{10}$$

where:

$P_{be_{est}}$ = estimated effective binder content,

P_s = percent of aggregate in the mixture (100-P_b)

G_b = specific gravity of the binder,

G_{se} = effective specific gravity of the aggregate,

G_{sb} = bulk specific gravity of the combined aggregate, and

$P_{b_{est}}$ = estimated binder content.

$$\text{Dust/Asphalt Ration} = \frac{P_{200}}{P_{\text{be}}} \tag{11}$$

where:

P_{200} = percent passing the No. 200 (0.075 mm) sieve.

9.3.7. Compare the estimated volumetric properties from each trial aggregate blend gradation at the adjusted design binder content with the criteria specified in Section 9-03.8(2) of the *Standard Specifications*. Choose the trial aggregate blend gradation that best satisfies the volumetric criteria.

Note 14: Table 2 presents an example of the selection of a design aggregate structure from three trial aggregate blend gradations.

Note 15: Many trial aggregate blend gradations will fail the VMA criterion. Generally, the % criterion will be met if the VMA criterion is satisfied. Section 12.1 gives a procedure for the adjustment of VMA.

Note 16: If the trial aggregate gradations have been chosen to cover the entire range of the gradation controls, then the only remaining solution is to make adjustments to the aggregate production or to introduce aggregates from a new source. The aggregates that fail to meet the required criteria will not produce a quality mix and should not be used. One or more of the aggregate stockpiles should be replaced with another material which produces a stronger structure. For example, a quarry stone can replace a crushed gravel, or crushed fines can replace natural fines.

Volumetric Property	**Trial Mixture (¾ Inch Nominal Maximum Aggregate) 15 Year Project Design ESALs = 5 million**			**Criteria**
	1	**2**	**3**	
	At the Initial Trial Binder Content			
P_b (trial)	4.4	4.4	4.4	
$\%G_{mm\ \mathrm{initial}}$(trial)	88.1	87.8	87.1	
$\%G_{mm\ \mathrm{design}}$(trial)	95.9	95.3	94.7	
V_a at N_{design}	4.1	4.7	5.3	4.0
VMA_{trial}	12.9	13.4	13.9	
	Adjustments to Reach Design Binder Content (V_a = 4.0% at N_{design})			
ΔV_a	–0.1	–0.7	–1.3	
ΔP_b	0.0	0.3	0.5	
ΔVMA	0.0	–0.1	–0.3	
	At the Estimated Design Binder Content (V_a = 4.0 % at N_{design})			
Estimated P_b (design)	4.4	4.7	4.9	
VMA (design)	12.9	13.3	13.6	≥ 13.0
$\%G_{mm\ \mathrm{initial}}$ (design)	88.2	89.5	88.4	≤ 89.0

Notes:

1. The top portion of this table presents measured densities and volumetric properties for specimens prepared for each aggregate trial blend at the initial trial binder content.
2. None of the specimens had an air void content of exactly 4.0 percent. Therefore, the procedures described in Section 9 must be applied to:
   (1) estimate the design binder content at which TV_a = 4.0 percent, and (2) obtain adjusted VMA and relative density values at this estimated binder content.

Selection of a Design Aggregate Structure (Example)
Table 2

3. The middle portion of this table presents the change in binder content (ΔP_b) and VMA (ΔVMA) that occurs when the target air void content (TV_a) is adjusted to 4.0 percent for each trial aggregate blend gradation.
4. A comparison of the VMA and densities at the estimated design binder content to the criteria in the last column shows that trial aggregate blend gradation No. 1 does not have sufficient VMA (12.9 percent versus a requirement of >13.0 percent). Trial blend No. 2 exceeds the criterion for relative density at N_{initial} gyrations (89.5 percent versus requirement of ≤89.0 percent). Trial No. 3 meets the requirement for relative density and VMA and, in this example, is selected as the design aggregate structure.

10. Selecting the Design Binder Content

10.1. Prepare replicate mixtures (Note 8) containing the selected design aggregate structure at each of the following three binder contents: (1) the estimated design binder content, $P_{b\,(\text{design})}$; (2) 0.5 percent below $P_{b\,(\text{design})}$; (3) 0.5 percent above $P_{b\,(\text{design})}$;

10.1.1. Use the number of gyrations previously determined in Section 8.1.

10.2. Condition the mixtures according to R 30, and compact the specimens to N_{design} gyrations according to WSDOT FOP for AASHTO T 312. Record the specimen height to the nearest 0.1 mm after each revolution.

10.3. Determine the bulk specific gravity of each of the compacted specimens in accordance with WSDOT FOP for AASHTO T 166 or AASHTO T 275 as appropriate.

10.4. Determine the theoretical maximum specific gravity (G_{mm}) according to WSDOT FOP for AASHTO T 209 of each of the three mixtures using companion samples which have been conditioned to the same extent as the compacted specimens (Note 8).

10.5. Determine the design binder content which produces a target air void content of 4.0 percent at N_{design} gyrations using the following steps:

10.5.1. Calculate V_a, VMA, and VFA at N_{design} using Equations 2, 3 and 12: The volumetric properties are determined for each specimen and then averaged for each replicate mixture.

$$VFA = 100 \times \left[\frac{VMA - V_a}{VMA}\right] \qquad (12)$$

10.5.2. Calculate the Dust/Asphalt Ratio, using Equation 13.

$$\textit{Dust/Asphalt Ratio} = \frac{P_{200}}{P_{\text{be}}} \qquad (13)$$

where:

P_{be} = effective binder content.

10.5.3. For each of the three mixtures, determine the average corrected specimen relative densities at N_{initial} (%), using Equation 14.

$$\%G_{mm_{\text{initial}}} = 100 \times \left(\frac{G_{mb} \quad h_d}{G_{mm} \quad h_i} \right) \tag{14}$$

10.5.4. Plot the average V_a, VMA, VFA, and relative density at N_{design} for replicate specimens versus binder content.

Note 17: All plots are generated automatically by the Superpave software. Figure 2 presents a sample data set and the associated plots.

10.5.5. By graphical or mathematical interpolation (Figure 2), determine the binder content to the nearest 0.1 percent at which the target V_a is equal to 4.0 percent. This is the design binder content (P_b) at N_{design}.

10.5.6. By interpolation (Figure 2), verify that the volumetric requirements specified in Section 9-03.8(2) of the *Standard Specifications* are met at the design binder content.

10.6. Compare the calculated percent of maximum relative density with the design criteria at N_{initial} by interpolation, if necessary. This interpolation can be accomplished by the following procedure.

10.6.1 Prepare a densification curve for each mixture by plotting the measured relative density at x gyrations, $\%G_{mm\ \mathrm{x}}$, versus the logarithm of the number of gyrations (see Figure 3).

10.6.2 Examine a plot of air void content versus binder content. Determine the difference in air voids between 4.0 percent and the air void content at the nearest, lower binder content. Determine the air void content at the nearest, lower binder content at its data point, not on the line of best fit. Designate the difference in air void content as ΔV_a.

10.6.3 Using Equation 14, determine the average corrected specimen relative densities at N_{initial}. Confirm that satisfies the design requirements in Section 9-03.8(2) of the *Standard Specifications* at the design binder content.

10.7. Prepare replicate (Note 8) specimens composed of the design aggregate structure at the design binder content to confirm that $\%G_{mm\ \max}$ satisfies the design requirements in Section 9-03.8(2) of the *Standard Specifications*.

10.7.1 Condition the mixtures according to R-30, and compact the specimens according to WSDOT FOP for AASHTO T312 to the maximum number of gyrations, $N_{\max}$, from Section 9-03.8(2) of the *Standard Specifications.*

10.7.2 Determine the average specimen relative density at $N_{\max}$, $\%G_{mm\ \max}$, by using Equation 15, and confirm that satisfies the volumetric requirement in Section 9-03.8(2) of the *Standard Specifications*.

$$\%G_{mm\ \max} = 100\,\frac{G_{mb}}{G_{mm}} \qquad (15)$$

where:

$\%\%G_{mm\ \max}$ = relative density at N_{max} gyrations at the design binder content.

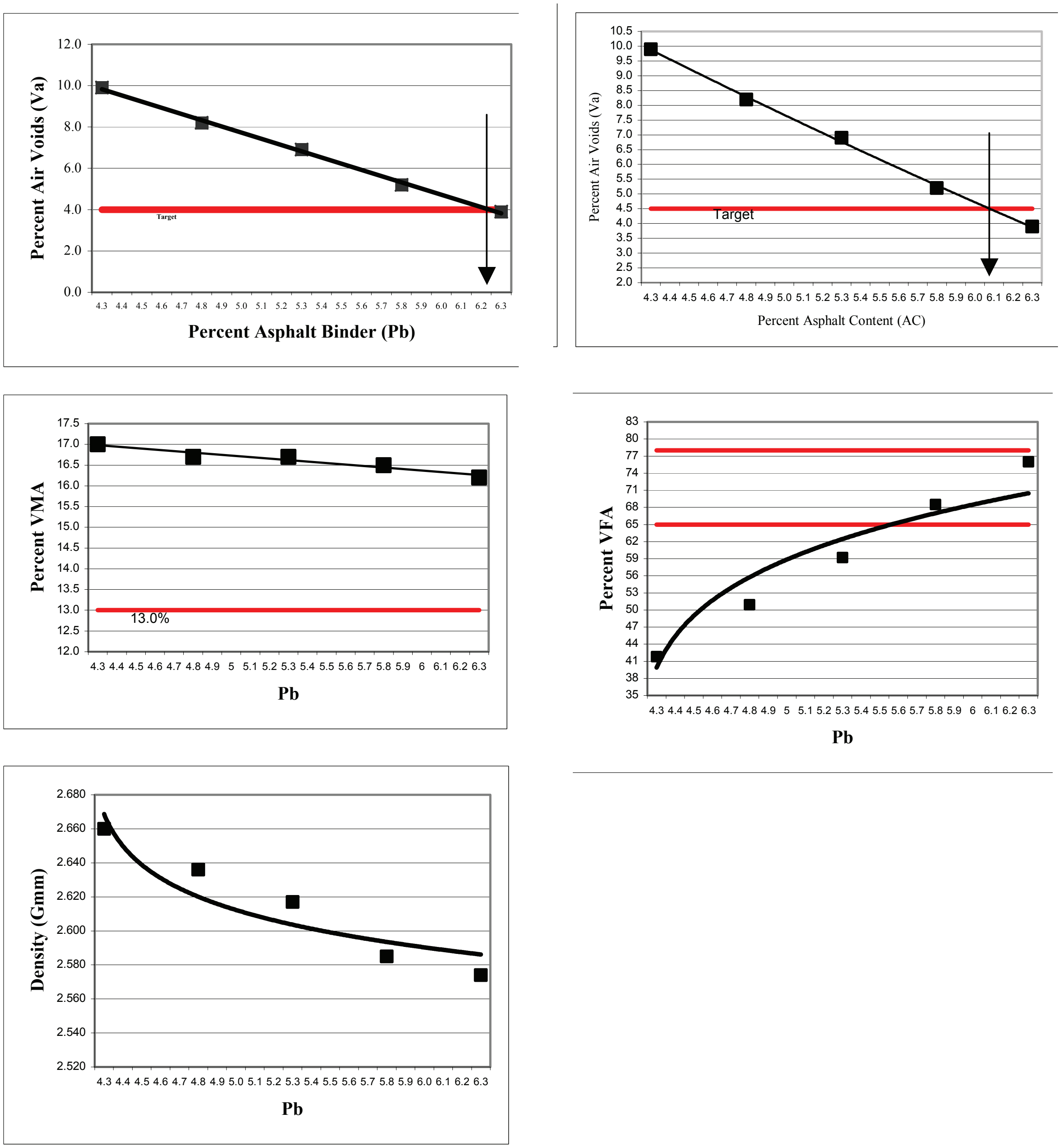
P_b(%)	V_a(%)	VMA (%)	VFA (%)	Maximum Density at N_{design} (G_{mm})	Density at N_{design} lbs/ft^3
4.3	9.9	17.0	41.8	2.660	165.6
4.8	8.2	16.7	50.9	2.636	164.1
5.3	6.9	16.6	58.5	2.617	162.9
5.8	5.2	16.5	68.5	2.585	160.9
6.3	3.9	16.2	76.0	2.574	160.2

In this example, the estimated design binder content is 4.8 percent; the minimum VMA requirement for the design aggregate structure (¾ inch nominal maximum size) is 13.0 percent, and the VFA requirements is 65 to 78 percent.

Entering the plot of percent air voids versus percent binder content at 4.0 percent air voids, the design binder content is determined as 6.2 percent.

Entering the plots of percent VMA versus percent binder content and percent VFA versus percent binder content at 6.2 percent binder content, the mix meets the VMA and VFA requirement.

Sample Volumetric Design Data at N_{des}
Figure 2



Sample Densification Curve

Figure 3

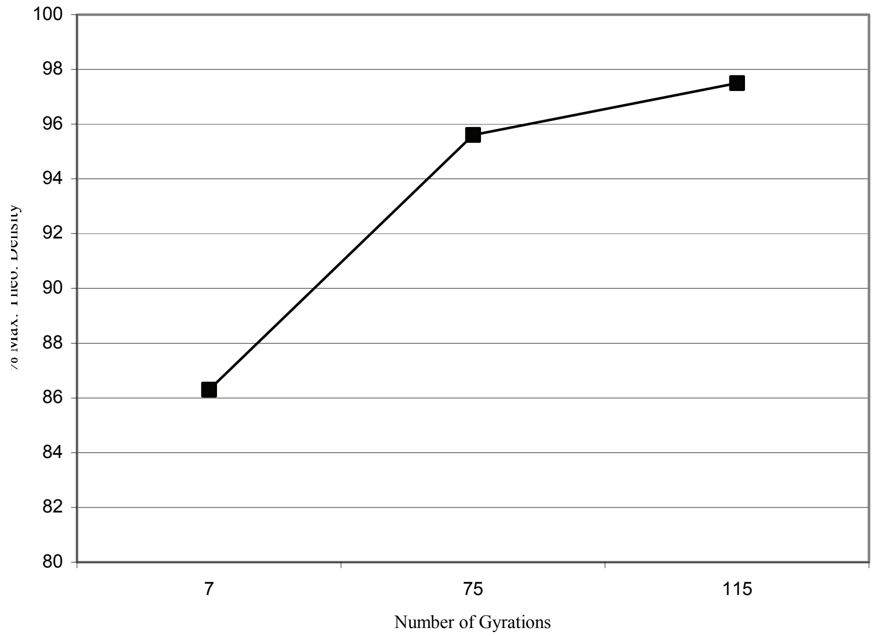


Figure 4

11. Evaluating Moisture Susceptibility

    11.1. Prepare six mixture specimens composed of the design aggregate structure at the design binder content. Prepare the specimens according to WSDOT T 726, and compact the specimens to approximate 4.0% air voids in accordance to WSDOT T 702. The WSDOT State Materials Laboratory will evaluate the HMA for moisture susceptibility.

    11.2. Test the specimens and calculate the tensile strength ratio in accordance with WSDOT T 718.

12. Adjusting the Mixture to Meet Properties

    12.1. *Adjusting VMA*—If a change in the design aggregate skeleton is required to meet the specified VMA, there are three likely options: (1) change the gradation (Note 18); (2) reduce the minus No. 200 (0.075-mm) fraction (Note 19); or (3) change the surface texture and/or shape of one or more of the aggregate fractions (Note 20).

    Note 18: Changing gradation may not be an option if the trial aggregate blend gradation analysis includes the full spectrum of the gradation control area.

    Note 19: Reducing the percent passing the No. 200 (0.075-mm) sieve of the mix will typically increase the VMA. If the percent passing the No. 200 (0.075-mm) sieve is already low, this is not a viable option.

    Note 20: This option will require further processing of existing materials or a change in aggregate sources.

12.2. *Adjusting VFA*—The lower limit of the VFA range should always be met at 4.0 percent air voids if the VMA meets the requirements. If the upper limit of the VFA is exceeded, then the VMA is substantially above the minimum required. If so, redesign the mixture to reduce the VMA. Actions to consider for redesign include: (1) changing to a gradation that is closer to the maximum density line; (2) increasing the minus No. 200 (0.075-mm) fraction, if room is available within the specification control points; or (3) changing the surface texture and shape of the aggregates by incorporating material with better packing characteristics, e.g., less thin, elongated aggregate particles.

13. Report

13.1. The report shall include the identification of the project number, mix class designation, and mix design number.

13.2. The report shall include information on the design aggregate structure including the source of aggregate, and gradation, including the blending ratios.

13.3. The report shall contain information about the design binder including the source of binder and the performance grade.

13.4. The report shall contain information about the HMA including the percent of binder in the mix; the relative density; the number of initial, design, and maximum gyrations; and the VMA, VFA, V_a, and Dust/Asphalt Ratio P_{be}, G_{mm}, G_{mb}, G_{sb} and G_{se} of the aggregate blend, G_{sb} of the fine aggregate, and G_b.

13.5. The report shall contain the results of the moisture susceptibility testing and the required level of anti-strip additive needed.

14. Keywords

14.1. HMA mix design; Superpave; volumetric mix design.

Appendix

A1. Calculating an Initial Trial Binder Content for Each Aggregate Trial Blend

Nonmandatory information

A1.1 Calculate the bulk and apparent specific gravities of the combined aggregate in each trial blend using the specific gravity data for the aggregate fractions obtained in Section 6.6 and Equations 16 and 17:

$$G_{sb} = \frac{P_1 + P_2 + \cdots + P_n}{\frac{P_1}{G_1} + \frac{P_2}{G_2} + \cdots + \frac{P_n}{G_n}} \quad (16)$$

$$G_{sa} = \frac{P_1 + P_2 + \cdots + P_n}{\frac{P_1}{G_1} + \frac{P_2}{G_2} + \cdots + \frac{P_n}{G_n}} \quad (17)$$

Where:

G_{sb} = bulk specific gravity for the combined aggregate;
G_{sa} = apparent specific gravity for the combined aggregate;
P_1, P_2, P_n = percentages by mass of aggregates 1, 2, n; and
G_1, G_2, G_n = bulk specific gravities (Equation 16) or apparent specific gravities (Equation 17) of aggregates 1, 2, *n*.

A1.2 Estimate the effective specific gravity of the combined aggregate in the aggregate trial blend using Equation 18:

$$G_{se} = G_{sb} + 0.8(G_{sa} - G_{sb}) \quad (18)$$

where:

G_{se} = effective specific gravity of the combined aggregate;
G_{sb} = bulk specific gravity of the combined aggregate; and
G_{sa} = apparent specific gravity of the combined aggregate.

Note 21: The multiplier, 0.8, can be changed at the discretion of the designer. Absorptive aggregates may require values closer to 0.6 or 0.5.

Note 22: The Superpave mix design system includes a mixture conditioning step before the compaction of all specimens; this conditioning generally permits binder absorption to proceed to completion. Therefore, the effective specific gravity of Superpave mixtures will tend to be close to the apparent specific gravity in contrast to other design methods where the effective specific gravity generally will lie near the midpoint between the bulk and apparent specific gravities.

A1.3 Estimate the volume of binder absorbed into the aggregate, V_{ba}, using Equations 19 and 20:

$$V_{ba} = W_s\left(\frac{1}{G_{sb}} - \frac{1}{G_{se}}\right) \quad (19)$$

where:

W_s = the mass of aggregate in 1 cm^3 of mix, g, is calculated as:

$$W_s = \frac{P_s(1 - V_a)}{\frac{P_b}{G_b} + \frac{P_s}{G_{se}}} \quad (20)$$

and where:

P_b = percent of binder, in decimal equivalent, assumed to be 0.05;
P_s = percent of aggregate <u>in mixture</u>, in decimal equivalent, assumed to be 0.95;
G_b = specific gravity of the binder; and
V_a = volume of air voids, assumed to be 0.04 cm^3 in 1 cm^3 of mix.

Note 23: This estimate calculates the volume of binder absorbed into the aggregate, V_{ba}, and subsequently, the initial, trial binder content at a target air void content of 4.0 percent.

A1.4 Estimate the volume of effective binder using Equation 21:

$$V_{be} = 0.176 - [0.0675 \log(S_n)] \quad (21)$$

where:

V_{be} = volume of effective binder, cm^3; and
S_n = nominal maximum sieve size of the largest aggregate in the aggregate trial blend, mm.

Note 24: This regression Equation is derived from an empirical relationship between: (1) VMA and V_{be} when the air void content, V_a, is equal to 4.0 percent: V_{be} = VMA – P_a = VMA – 4.0; and (2) the relationship between VMA and the nominal maximum sieve size of the aggregate in MP 2. For WSDOT projects, see contract provisions.

A1.5 Calculate the estimated initial trial binder (P_{bi}) content for the aggregate trial blend gradation using Equation 22:

$$P_{bi} = 100 \times \left(\frac{G_b(V_{be} + V_{ba})}{(G_b(V_{be} + V_{ba})) + W_s}\right) \quad (22)$$

where:

P_{bi} = estimated initial trial binder content, percent by weight of total mix.

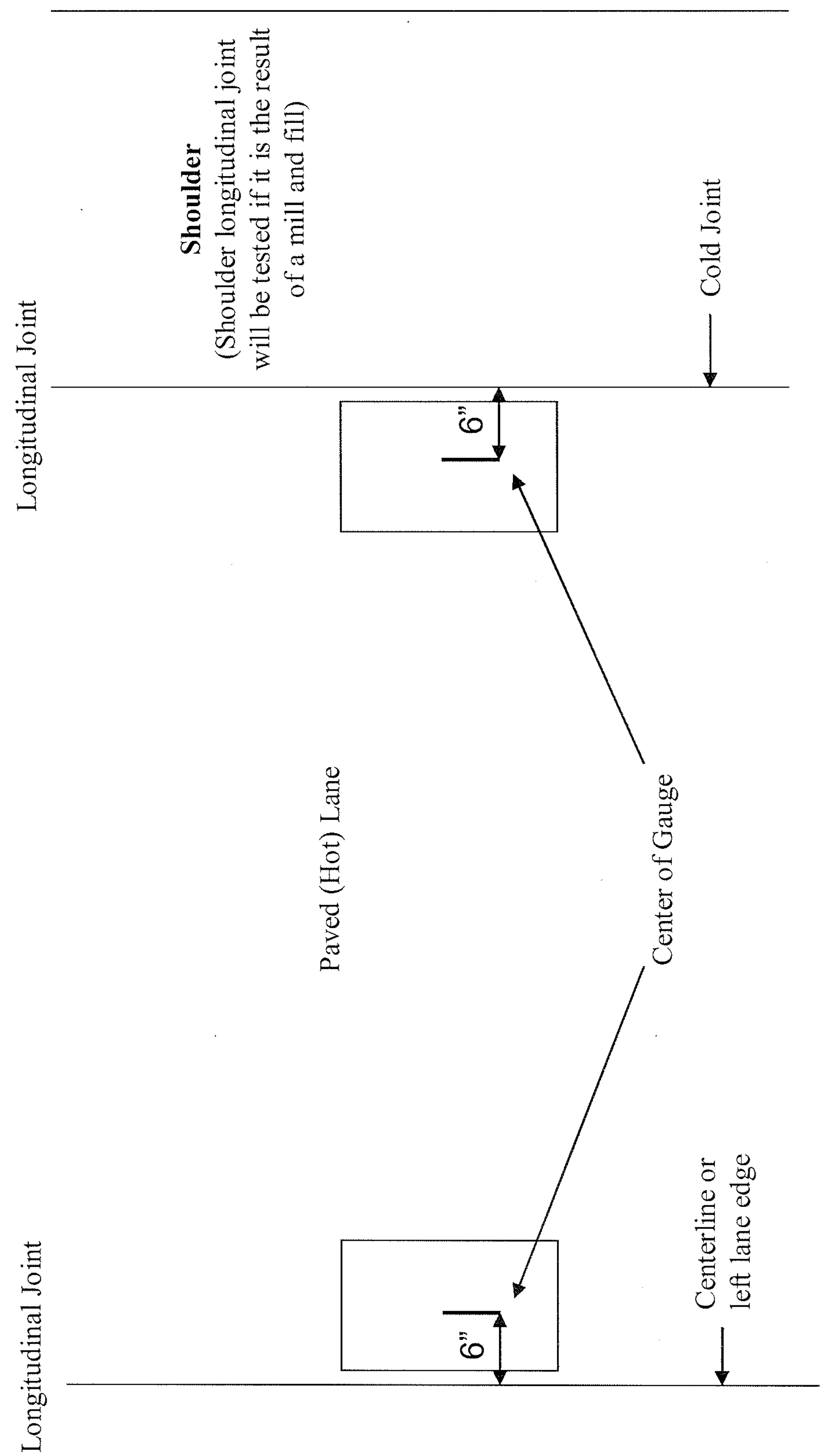
WSDOT SOP 735

Standard Operating Procedure for Longitudinal Joint Density

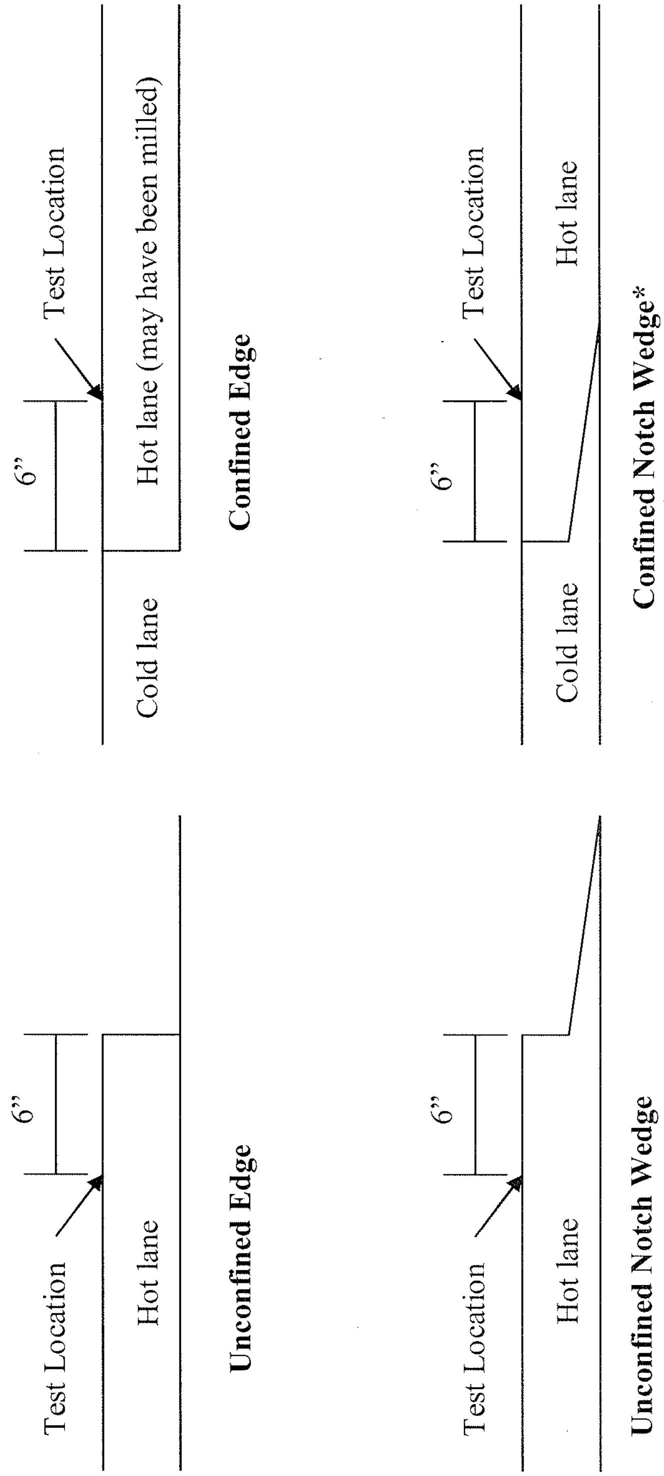
1. GENERAL SCOPE
   a. This procedure describes the method for determining the location of a longitudinal joint density test.
   b. Longitudinal joint density tests are performed in addition to Quality Assurance (QA) density tests
   c. One longitudinal joint density test will be performed on the confined or unconfined edge at each longitudinal joint.
2. LONGITUDINAL JOINT TESTING
   a. The longitudinal joint <u>density</u> test will be conducted in accordance with WSDOT FOP for WAQTC TM-8, except "Test Site Location, Section 1, subsection c, which is modified by this procedure to read "No closer than 18 in. (450mm) to any vertical mass, or less than 6 in. (152 mm) from a vertical pavement edge," making sure the gauge will sit flush with the hot-mix asphalt (HMA). See Figure 1.
   b. A longitudinal joint density will be required on the lane edge side of a shoulder if the shoulder is required to meet the same QA density requirements as the traveled lane.

   Note: Hot lap joints are not included in longitudinal joint testing.
3. NUMBER OF LONGITUDINAL JOINT TESTS
   a. <u>For projects requiring 400 tons sublot with 5 sublots -</u> One reading, at each longitudinal joint to be tested, will be taken within each compaction lot at the same station location as the third sublot.
   b. For projects requiring 80 ton sublots- One reading, at each longitudinal joint to be tested, will be taken every four hundred tons or at every fifth sublot tested.
4. CALCULATION OF RESULTS
   a. Calculate the Longitudinal Joint density <u>in accordance</u> WSDOT SOP 729.
5. REPORT
   a. Report the test results on the 'Data sheet Longitudinal Joint DOT Form 350-095 EF.

   Note: Lot Number corresponds to the lot where the set of longitudinal joint readings were taken. The station corresponds to the station within the lot (i.e. third sublot) where the set of longitudinal joint readings were taken.



Longitudinal Joint Testing Locations
Figure 1



* The test location of a confined notch wedge may or may not be located on the slope of the cold lane paved.

Longitudinal Test Location Examples
Figure 2

Washington State
Department of Transportation

WSDOT Test Method T 810

Method of Test for Determination of the Density of Portland Cement Concrete Pavement Cores

1. SCOPE

   a. This method of test is intended for use in determining the density of Portland cement concrete pavement cores. The object of this test is to determine the in place density of the concrete as it exists. This density is the value desired for comparison to the density of freshly mixed portland cement as determined by AASHTO T 121 or by the densities on the mix design.

2. EQUIPMENT

   a. Balance — Capacity sufficient for the masses required by the test procedure, accurate to 0.1 percent of the sample mass or better and conforms to the requirements of AASHTO M 231.

   b. Wire Basket — A wire basket of appropriate size, constructed of wire mesh.

   c. Container — A container suitable for immersing the wire basket in water, and an apparatus for suspending the wire basket from the center of the scale pan of the balance. Maintain a constant water level when weighing under water.

   d. Absorbent towels.

   e. Temperature Measuring Device — The temperature measuring device shall be verified and readable to 1°F (0.5°C). Thermometers having a range of 0 to 120°F (-18 to 49°C) are satisfactory. Other thermometers of the required accuracy, including the metal immersion type and conforming to ASTM E 1, are acceptable.

3. PROCEDURE

   a. Density determinations are made as soon as practicable after coring and with a minimum change in moisture content from the condition as taken. Where on-site determination is not practicable within one hour, cores are stored in airtight plastic bags or completely immersed in water until weighed. Core densities shall be determined within 4 hours after coring.

Temperature °F	Pounds per Cubic Foot
65	62.336
66	62.329
67	62.322
68	62.315
69	62.308
70	62.301
71	62.293
72	62.285
73	62.277
74	62.269
75	62.261
80	62.216

Unit Mass of Water
Table 1

b. Wash thoroughly to remove dust or other coatings from the surface of the core. Place the sample in the wire basket and determine its mass in water. Determine this and all subsequent weights to the nearest gram. Determine the temperature of the water to the nearest degree.

c. Remove the sample from the water and roll it in a large absorbent cloth until all visible films of water are removed, although the surfaces still appear to be damp. Take care to avoid evaporation from aggregate pores during the operation of surface drying. Obtain the weight of the sample in the surface dry condition.

4. CALCULATION

a. Calculate the density as follows:

$$\text{Density (surface-dry basis)} = \frac{A}{A - B} \times d_w$$

where:

A = mass in grams of the surface-dry sample in air

B = mass in grams of the sample in water

dw = density of the water at the test temperature (see Table 1)

Calculate the density to the nearest 0.1 lb. per ft.^{3} (1 kg per m^3).

5. REPRODUCIBILITY OF RESULTS

a. Duplicate determinations should check to within 0.1 lb. per ft.^{3} (3 kg per m^3).

6. REPORTS

a. The test results will be reported on the appropriate test data sheet.

Performance Exam Checklist

Method of Test for Determination of the Density of PCC Pavement Cores (WSDOT TM 810)

Participant Name ______________________________ Exam Date _______________

Procedure Element	**Yes**	**No**
1. The tester has a copy of the current procedure on hand?	❐	❐
2. All equipment is functioning according to the test procedure, and if required, has the current calibration/verification tags present?	❐	❐
3. Density determined approximately 24 hours after concrete placement?	❐	❐
4. Core's moisture content preserved in bags or by immersion?	❐	❐
5. Density determined within 4 hours of coring?	❐	❐
6. Core washed thoroughly?	❐	❐
7. Weight in water determined to nearest gram?	❐	❐
8. Temperature of water determined to nearest degree?	❐	❐
9. Core rolled on absorbent towel removing visible films of water but still appearing damp?	❐	❐
10. Core not over-dried or allowed to evaporate?	❐	❐
11. Weight of surface-dry core determined to nearest gram?	❐	❐
12. All calculations performed correctly?	❐	❐

First attempt: Pass ❐ Fail ❐ Second attempt: Pass ❐ Fail ❐

Signature of Examiner ____________________________________

Comments:

WSDOT Test Method T 812

Method of Test for Measuring Length of Drilled Concrete Cores

1. SCOPE

   a. This method is for the WSDOT ten point callipering device it is similar to AASHTO T-148 and covers the procedure for determining the length of a core drilled from a concrete structure, and from Portland cement concrete pavement. It is acceptable to use the commercially available nine point callipering device defined in AASHTO T 148.

2. APPARATUS

   a. The apparatus shall be a callipering device that will measure the length of axial elements of the core. While the details of the mechanical design are not prescribed, the apparatus shall conform to the requirements of 2 (B) to 2 (F).

   b. The apparatus shall be designed so that the specimen will be held with its axis in a vertical position by three symmetrically placed supports bearing against the lower end. These supports shall be short posts or stubs of hardened steel, and the ends that bear against the surface of the specimen shall be rounded to a diameter of not less than ¼ inch more than ½ inch.

   c. The apparatus shall provide for the accommodation of specimens of different nominal lengths. (A range of at least 9 to 12 inches.)

   d. The callipering apparatus shall be designed so that it will be possible to make a length measurement at the center of the upper end of the specimen and at nine additional points (See Note 1) spaced at equal intervals along the circumference of a circle whose center point coincides with that of the end area of the specimen and whose radius is not less than one-half nor more than three-fourths of the radius of the specimen.

      Note 1: Commercially available nine point callipering device is acceptable.

   e. The measuring rod or other device that makes contact with the end surface of the specimen for measurement shall be rounded to a radius of ⅛ inch. The scale on which the length readings are made shall be marked with clear, definite, accurately-spaced graduations. The spacing of the graduations shall be 0.10 inch or a decimal part thereof.

   f. The apparatus shall be stable and sufficiently rigid to maintain its shape and alignment without a distortion or deflection of more than 0.01 inch during all normal measuring operations.

3. TEST SPECIMENS

    a. Cores used as specimens for length measurement shall be in every way representative of the concrete in the structure from which they are removed. The specimen shall be drilled with the axis normal to the surface of the structure, and the ends shall be free from all conditions not typical of the surfaces of the structure. Cores that show abnormal defects or that have been damaged appreciably in the drilling operation shall not be used.

4. PROCEDURE

    a. Before any measurement of the core length is made, the apparatus is calibrated with suitable gauges so that errors caused by mechanical imperfections in the apparatus are known. When these errors exceed 0.01 inch, suitable corrections are applied to the core length measurements.

    b. The specimen is placed in the measuring apparatus with the smoothest end of the core facing down, to bear against the three hardened-steel supports. The specimen is placed on the supports so that the central measuring position of the measuring apparatus is directly over the mid-point of the upper end of the specimen.

    c. Ten measurements (See Note 2) of the length are made on each specimen, one at the central position and one each at nine additional positions spaced at equal intervals along the circumference of a circle of measurement as described in 2(D). Each of these ten measurements is read directly to 0.10 inch and to 0.01 inch either directly or by estimation.

        Note 2: For commercially available callipering devices nine measurements is allowed.

    d. If, in the course of the measuring operation, it is discovered that at one or more of the measuring points the surface of the specimen is not representative of the general plane of the core end because of a small projection or depression, rotate the specimen slightly about its axis, and make a complete set of nine measurements in the new position.

5. REPORT

    a. The individual observations are recorded to the nearest 0.01 inch and the average of the ten measurements (See Note 3), expressed to the nearest 0.01 foot, are reported on DOT Form No. 350-067 under the column "Measured Thickness."

        Note 3: For commercially available callipering devices average nine measurements.

Performance Exam Checklist

Method T 812 Checklist
Measuring Length of PCC Cores

Participant Name ______________________________ Exam Date ______________

Procedure Element	**Yes**	**No**
1. Only concrete measured?	❒	❒
2. Damaged cores not measured?	❒	❒
3. Apparatus calibrated?	❒	❒
4. Smooth (top) end of core set on pins?	❒	❒
5. Center probe located at center of core?	❒	❒
6. Ten measurements taken?	❒	❒
7. Measurements read to 0.10 in. directly?	❒	❒
8. Measurements read indirectly to 0.01 in.?	❒	❒
9. Measurements recorded to 0.01 in.?	❒	❒
10. Averaged and reported to 0.01 foot?	❒	❒

First attempt: Pass ❒ Fail ❒ Second attempt: Pass ❒ Fail ❒

Signature of Examiner ____________________________________

Comments:

Washington State
Department of Transportation

WSDOT Test Method T 813

Field Method of Fabrication of 2-in. (50-mm) Cube Specimens for Compressive Strength Testing of Grouts and Mortars

1. SCOPE

   This method covers the fabrication of 2-in. (50-mm) cube specimens for compressive strength testing of grouts and mortars.

2. EQUIPMENT

   a. Specimen Molds

      Specimen molds for the 2-in. (50-mm) cube specimens shall be tight fitting. The molds shall not have more than three cube compartments and shall not be separable into more than two parts. The parts of the molds, when assembled, shall be positively held together. The molds shall be made of hard metal not attacked by the cement mortar. For new molds, the Rockwell hardness number shall not be less than HRB 55. The sides of the molds shall be sufficiently rigid to prevent spreading or warping. The interior faces of the molds shall conform to the tolerances of Table 1.

	2 in. Cube Molds		**50-mm Cube Molds**	
Parameter	**New**	**In Use**	**New**	**In Use**
Planeness of Sides	<0.001 in.	<0.002 in.	<0.025 mm	<0.05 mm
Distance Between Opposite Sides	2 in. + 0.005 in.	2 in. + 0.02 in.	50 mm + 0.13 mm	50 mm + 0.50 mm
Height of Each Compartment	2 in. + 0.001 in. to -0.005 in.	2 in. + 0.01 in. to -0.015 in.	50 mm + 0.25 mm to -0.013 mm	50 mm + 0.25 mm to -0.38 mm
Angle Between Adjacent Faces[A]	90 + 0.5°	90 + 0.5°	90 + 0.5°	90 + 0.5°

A Measured at points slightly removed from the intersection. Measured separately for each compartment between all the interior faces and the adjacent face and between interior faces and top and bottom planes of the mold.

Permissible Variations of Specimen Molds
Table 1

   b. Base Plates

      Base plates shall be made of a hard metal not attacked by cement mortar. The working surface shall be plane and shall be positively attached to the mold with screws into the side walls of the mold.

c. Cover Plates

Cover plates shall be made of a hard metal or glass not attacked by cement mortar. The surface shall be relatively plane.

d. Tamper

The tamper shall be made of a nonabsorptive, nonabrasive, nonbrittle material such as a rubber compound having a Shore A durometer hardness of 80 + 10, or seasoned oak wood rendered nonabsorptive by immersion for 15 minutes in paraffin at approximately 392° F (200° C), and shall have a cross-section of ½ in. × 1 in. (13 mm × 25 mm) and a length of about 5 to 6 in. (125 to 150 mm). The tamping face shall be flat and at right angles to the length of the tamper.

e. Trowel

A trowel which has a steel blade 4 to 6 in. (100 to 150 mm) in length, with straightedges.

3. FIELD PROCEDURE

a. Three or more specimens shall be made for each period of test specified.

b. All joints shall be water tight. If not water tight, seal the surfaces where the halves of the mold join by applying a coating of light cup grease. The amount should be sufficient to extrude slightly when the halves are tightened together. Repeat this process for attaching the mold to the base plate. Remove any excess grease.

c. Apply a thin coating of release agent to the interior faces of the mold and base plate. (WD-40 has been found to work well as a release agent) Wipe the mold faces and base plate as necessary to remove any excess release agent and to achieve a thin, even coating on the interior surfaces. Adequate coating is that which is just sufficient to allow a distinct fingerprint to remain following light finger pressure.

d. Begin molding the specimens within an elapsed time of not more than 2½ minutes from completion of the mixing.

e. For plastic mixes, place a first layer of mortar about 1 in. (25 mm) deep in all the cube compartments (about one-half the depth of the mold). Tamp the mortar in each cube compartment 32 times in about 10 seconds making four rounds, each round perpendicular to the other and consisting of eight adjoining strokes over the surface of the specimen, as illustrated in Figure 1, below. The tamping pressure should be just sufficient to ensure uniform filling of the molds. The four rounds of tamping (32 strokes) shall be completed in one cube before going on to the next. When the tamping of the first layer is completed, slightly over fill the compartments with the remaining mortar and then tamp as specified for the first layer. During tamping of the second layer, bring in the mortar forced out onto the tops of the molds after each round of tamping, by means of gloved fingers and the tamper, before starting the next round of tamping. On completion of tamping, the tops of all the cubes should extend slightly above the tops of the molds.

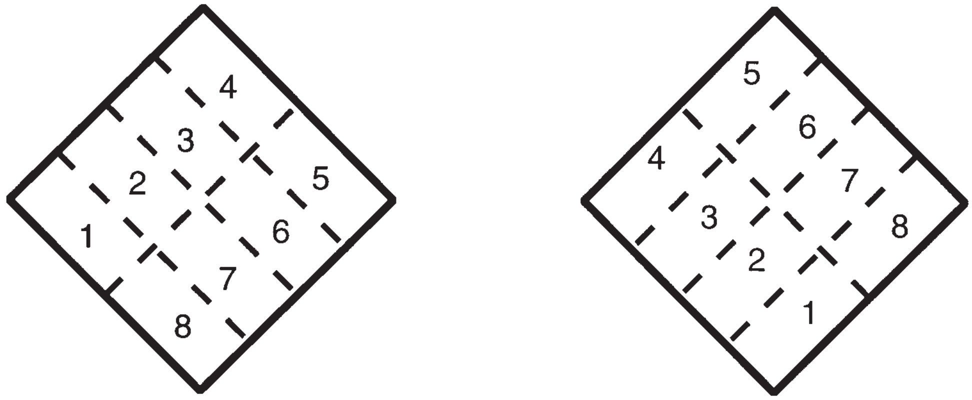


Figure 1

f. Bring in the mortar that has been forced out onto the tops of the molds with a trowel and smooth off the cubes by drawing the flat side of the trowel (with the leading edge slightly raised) once across the top of each cube at right angles to the length of the mold. Then, for the purpose of leveling the mortar and making the mortar that protrudes above the top of the mold of more uniform thickness, draw the flat trailing edge of the trowel (with leading edge slightly raised) once lightly along the length of the mold. Cut off the mortar to a plane surface flush with the top of the mold by drawing the straight edge of the trowel (held nearly perpendicular to the mold) with a sawing motion over the length of the mold.

g. When fabricating fluid mixes, steps e. and f. need not be followed. Instead, the cube mold is filled with mortar and cut off to a plane surface with a sawing motion over the length of the mold.

h. Immediately after molding, place cover plate on top of the mold, cover the sample with wet burlap, towels, or rags, seal it in a plastic sack in a level location out of direct sunlight, avoid freezing of cubes and record the time. Allow the sample to set undisturbed, away from vibration, for a minimum of four ~~six~~ hours before moving.

i. Deliver the sample to the Regional or State Materials Laboratory **in the mold** with the cover plate in wet burlap, towels or rags sealed in a plastic bag within 24 hours. **Time of molding MUST be recorded on the Concrete Transmittal.** If delivery within 24 hours is unachievable, contact the Laboratory for instructions on caring for the cubes.

j. Once received in the lab, the molded sample is to be immediately placed in a moist curing room, with the upper surfaces exposed to the moist air but protected from dripping until the sample is a minimum of 20 hours old or has cured sufficiently that removal from the mold will not damage the cube. If the specimens are removed from the mold before they are 24 hours old they are to be kept on the shelves of the moist curing room until they are 24-36 hours old.

k. When the specimens are 24-36 hours old, immerse them in a lime-saturated water storage tank. (Note 1) The specimens are to remain in the storage tank until time of test. (Curing test specimens of material other than hydraulic cement shall be in conformance with the manufacturer's recommendations.)

Note 1: The storage tank shall be made of noncorroding materials. The water shall be saturated with calcium hydroxide such that excess is present. Stir the lime-saturated water once a month and clean the bath as required by AASHTO M-201.

Performance Exam Checklist

Field Method of Fabrication of 50-mm (2-in.) Cube Specimens for Compressive Strength Testing of Grouts and Mortars
WSDOT Test Method T 813

Participant Name ______________________________ Exam Date _______________

Procedure Element	Yes	No
1. The tester has a copy of the current procedure on hand?	❒	❒
2. All equipment is functioning according to the test procedure, and if required, has the current calibration/verification tags present?	❒	❒
3. Three cubes made for each time period of test?	❒	❒
4. All joints (mold halves, mold to base plate) shall be water tight?	❒	❒
5. Adequate coating of release agent applied to interior surfaces of the mold?	❒	❒
6. Molding began within 2½ minutes from completion of mixing?	❒	❒
7. Molding performed in two lifts? (not necessary if mix is fluid)	❒	❒
8. Lifts tamped 32 times, made up of 4 rounds of 8, each perpendicular to the other? (not required if mix is fluid)	❒	❒
9. For second layer, mortar forced out of the mold brought back in before each round? (not required if mix is fluid)	❒	❒
10. Mix extends slightly above the mold at the completion of tamping?	❒	❒
11. Mortar smoothed by drawing flat side of trowel across each cube at right angles?	❒	❒
12. Mortar leveled by drawing the flat side of trowel lightly along the length of mold?	❒	❒
13. Mortar cut off flush with mold with edge of trowel using sawing motion?	❒	❒
14. Time of molding recorded?	❒	❒
15. Cover plate placed on top of the mold and covered with wet burlap, towel or rag?	❒	❒
16. Covered sample sealed in a plastic sack in a level location out of sunlight?	❒	❒
17. Sample delivered to the laboratory in the mold within 24 hours?	❒	❒
18. Transmittal includes the time of molding?	❒	❒

First attempt: Pass ❒ Fail ❒ Second attempt: Pass ❒ Fail ❒

Signature of Examiner ____________________________________

Comments:

Washington State
Department of Transportation

WSDOT Test Method T 819

Making and Curing Self-Compacting Concrete Test Specimens in the Field

1. The cylinders will be made and cured in accordance with WSDOT FOP for AASHTO T 23 with the following modifications:

   9. Molding Specimens

      9.2 Casting Cylinders is revised to read:

      Place the concrete in the mold using a scoop, blunted trowel or shovel. Molds shall be filled in one lift by pouring material from a suitable container into the mold. Do not rod, vibrate or tap the mold.

      9.3 Consolidation is deleted

      9.4 Finishing is revised to read:

      Strike off the surface of the concrete level with the top of the mold using a float, trowel or steel strike off bar. Immediately after finishing place a plastic cylinder lid on the cylinder.

Performance Exam Checklist

Making and Curing Self-Compacting Concrete Test Specimens in the Field WSDOT T 819

Participant Name ______________________ Exam Date ______________

Procedure Element	Yes	No
1. The tester has a copy of the current procedure on hand?	❒	❒
2. Molds placed on a level, rigid, horizontal surface free of vibration?	❒	❒
3. Making of specimens begun within 15 minutes of sampling?	❒	❒
4. Concrete poured into the mold using a suitable container?	❒	❒
5. Mold filled in one lift?	❒	❒
6. Excess concrete struck off?	❒	❒
7. Specimens covered immediately with plastic cylinder lid?	❒	❒

First attempt: Pass ❒ Fail ❒ Second attempt: Pass ❒ Fail ❒

Signature of Examiner ______________________________

This checklist is derived, in part, from copyrighted material printed in ACI CP-1, published by the American Concrete Institute.

Comments:

WSDOT Test Method T 914

Practice for Sampling of Geosynthetic Material for Testing

1. SCOPE
   a. This practice covers the procedure for sampling Geosynthetic Material for testing.
2. DEFINITIONS
   a. Geogrid- A regular network of integrally connected polymer tensile elements with an aperture geometry sufficient to permit mechanical interlock with the surrounding backfill.
   b. Geosynthetic Material- general term which includes all geotextiles, geogrids, and prefabricated drainage mats.
   c. Geotextile — Any permeable textile used with foundation, soil, rock, earth, or any other geotechnical material, as an integral part of a manmade product, structure, or system.
   d. Lot — All geosynthetic material rolls within a consignment (i.e., all rolls sent to the project site) which were manufactured at the same manufacturing plant having the same product name and specifications, style, or physical characteristics of a particular geosynthetic material product.
   e. Lot Sample — Sample(s) from one or more geosynthetic material rolls taken at random to represent an acceptance sampling lot and used as a source of laboratory samples.
   f. Production Unit — As referred to in this practice, it shall be considered to be synonymous with the geosynthetic material roll as shipped by the manufacturer. Two or more geosynthetic material rolls joined together by sewn seams shall be considered as separate rolls.
   g. Minimum Average Roll Value — The test results of any sampled roll in a lot shall meet or exceed the minimum values specified.
3. SIGNIFICANCE AND USE
   a. Sampling is an important part of testing and the sampler should make every effort to obtain samples that will show the nature and condition of the materials they represent.
   b. This sampling procedure will provide a representation of the lot which is adequate to establish minimum average roll values as defined by this practice.
4. PROCEDURE
   a. Divide the shipment or consignment into lots as defined in 2.d.
   b. Determine the number of rolls in the shipment or consignment to be sampled using Table 1.

Number of Rolls in Lot	Number of Rolls to be Selected for Lot Sample
1 to 24	1
25 to 49	2
50 to 99	3
100 to 125	5
125 to 216	6
217 to 343	7
344 to 512	8
513 to 729	9
730 to 1,000	10

Number of Rolls to be Selected as Lot Sample
Table 1

c. Laboratory sample selection.

(1) Obtain a laboratory sample from each roll in the Lot Sample. The sample shall be a minimum of 6 feet long by the full width of the geosynthetic material roll with a total area greater than or equal to 6.0 yd^2.

(2) The laboratory sample should not be taken from the outer wrap of the roll nor the inner wrap of the core (i.e., do not take the sample from the very ends of the roll).

(3) Protect the sample from exposure to Ultraviolet light.

5. SAMPLE SUBMITTAL

a. All geotextile samples submitted to the State Material Laboratory are to be prepared and shipped as follows:

Roll sample around a 4-in diameter minimum, tube such as PCV pipe or cardboard mailing tube and wrap to protect sample from shipping damage and ultraviolet light (UV) exposure.

b. If sample is for Acceptance of Lots used on project, the following information must be submitted with the sample:

(1) Manufacturer's name and current address.

(2) Full product name.

(3) Roll number(s).

(4) Proposed use(s).

(5) Certified test results from the manufacturer.

(6) The Lot Number being submitted for acceptance. In lieu of a manufacturer provided Lot Number, the Bill of Lading Number can be used.

Testing by the State Materials Laboratory will not begin until all of the required information is received.

Performance Exam Checklist

Practice for Sampling Geosynthetic Material for Testing
WSDOT Test Method T 914

Participant Name ______________________________ Exam Date ______________

Procedure Element	**Yes**	**No**
1. The tester has a copy of the current procedure on hand?	❒	❒
2. Sampling	❒	❒
a. Divided shipment/consignment into lot(s) and used Table 1 to determine the number of rolls to be sampled.	❒	❒
b. Rolls to be sampled selected at random.	❒	❒
c. Samples are a minimum of 6 feet long by the full width of the geosynthetic material roll with a total area greater than or equal to 6.0 yd^2	❒	❒
d. Sample does not include outer wrap or inner wrap of the roll.	❒	❒
3. Shipment Preparation	❒	❒
a. Roll sample around a 4-in diameter minimum, tube such as PCV pipe or cardboard mailing tube	❒	❒
b. Wrap the sample to protect from ultra-violet light exposure.		

First attempt: Pass ❒ Fail ❒ Second attempt: Pass ❒ Fail ❒

Signature of Examiner ________________________________

Comments:

WSDOT FOP for ASTM C 1611/C 1611M[1]

Standard Test Method for Slump Flow of Self-Consolidating Concrete

1. Scope

   1.1 This test method covers the determination of slump flow of self-consolidating concrete.

   1.2 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in nonconformance with the standard.

   1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* (**WARNING** - Fresh hydraulic cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged exposure.)

   1.4 The text of this standard references notes and footnotes that provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the standard.

2. Referenced Documents

   2.1 *ASTM Standards*:

C 143/C 143M	Test Method for Slump of Hydraulic-Cement Concrete
C 172	Practice for Sampling Freshly Mixed Concrete
C 173/C 173M	Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method
C 670	Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

   2.2 AASHTO Standards

T 119M/T 119	Standard Test Method for Slump of Hydraulic-Cement Concrete
TP 73-09	Slump Flow of Self-Consolidating Concrete (SCC)

   2.3 WAQTC Standard

TM 2	Sampling Freshly Mixed Concrete

[1] This Test Method is based on ASTM C 1611/C 1611M and has been modified per WSDOT standards. To view the redline modifications, contact WSDOT Quality Systems Manager at (360) 709-5412.

3. Terminology

3.1 Definitions of Terms Specific to This Standard:

3.1.1 *halo, n*—an observed cement paste or mortar ring that has clearly separated from the coarse aggregate, around the outside circumference of concrete after flowing from the slump cone.

3.1.2 *spread, n*—the distance of lateral flow of concrete during the slump-flow test.

3.1.3 *stability, n*—the ability of a concrete mixture to resist segregation of the paste from the aggregates.

3.1.4 *viscosity, n*—resistance of a material to flow under an applied shearing stress.

4. Summary of Test Method

4.1 A sample of freshly mixed concrete is placed in a mold shaped as the frustum of a cone. The concrete is placed in one lift without tamping or vibration. The mold is raised, and the concrete allowed to spread. After spreading ceases, two diameters of the concrete mass are measured in approximately orthogonal directions, and slump flow is the average of the two diameters.

5. Significance and Use

5.1 This test method provides a procedure to determine the slump flow of self-consolidating concrete in the laboratory or the field.

5.2 This test method is used to monitor the consistency of fresh, unhardened self-consolidating concrete and its unconfined flow potential.

5.3 It is difficult to produce self-consolidating concrete that is both flowable and nonsegregating using coarse aggregates larger than 1 in. (25 mm). Therefore, this test method is considered applicable to self-consolidating concrete having coarse aggregate up to 1 in. (25 mm) in size.

6. Apparatus

6.1 *Mold*—The mold used in this test method shall conform to that described in FOP for AASHTO T 119.

6.2 *Base Plate*—The base plate on which the mold rests shall be nonabsorbent, smooth, rigid, and have a minimum diameter of 36 in. (915 mm).

NOTE 1: *Field experience and results from the round robin test program have shown that base plates made from sealed/laminated plywood, acrylic plastic, or steel are suitable for performing this test.*

6.3 *Strike-off Bar*—As described in FOP for AASHTO T 152.

7. Sample

7.1 The sample of concrete from which test specimens are made shall be representative of the entire batch. Sample in accordance with FOP for WAQTC TM 2.

8. Procedure

8.1 The slump-flow test shall be performed on a flat, level, nonabsorbent base plate. Position and shim the base plate so it is fully supported, flat, and level.

8.2 *Filling the Mold:* WSDOT requires the use of Procedure B.

8.2.1 *Filling Procedure B (Inverted Mold):* Dampen and place the mold, with the smaller opening of the mold facing down, in the center of a flat, moistened base plate or concrete surface.Using a suitable container, fill the entire mold continuously. The mold shall be held firmly in place during filling. Do not rod or tamp the SCC. Slightly overfill the mold.

8.3 Strike off the surface of the concrete level with the top of the mold by a sawing motion of the strike-off bar. Remove concrete from the area surrounding the base of the mold to preclude interference with the movement of the flowing concrete. Remove the mold from the concrete by raising it vertically. Raise the mold a distance of 9 ± 3 in. (225 ± 75 mm) in 3 ± 1 seconds by a steady upward lift with no lateral or torsional motion. Complete the entire test from start of the filling through removal of the mold without interruption within an elapsed time of 2½ minutes.

8.4 Wait for the concrete to stop flowing and then measure the largest diameter of the resulting circular spread of concrete to the nearest ¼ in. (5 mm). When a halo is observed in the resulting circular spread of concrete, it shall be included as part of the diameter of the concrete. Measure a second diameter of the circular spread at an angle approximately perpendicular to the original measured diameter.

8.5 If the measurement of the two diameters differs by more than 2 in. (50 mm), the test is invalid and shall be repeated.

9. Calculation

9.1 Calculate the slump flow using Eq 1:

$$\text{Slump flow} = \frac{(d^1 + d^2)}{2}$$

where:

d^1 = the largest diameter of the circular spread of the concrete, and

d^2 = the circular spread of the concrete at an angle approximately perpendicular to d^1

9.2 Record the average of the two diameters to the nearest ¼ in. (5 mm).

10. Report

10.1 Report the slump flow to the nearest ¼ in. (5 mm).

11. Precision and Bias

See ASTM C1611/C 1611M for precision and bias.

Performance Exam Checklist

WSDOT FOP for ASTM C 1611/C 1611M
Standard Test Method for Slump Flow of Self-Consolidating Concrete

Participant Name ______________________ Exam Date ______________

Procedure Element	**Yes**	**No**
1. The tester has a copy of the current procedure on hand?	❒	❒
2. All equipment is functioning according to the test procedure, and if required. Has the current calibration/verification tags present?	❒	❒
3. Sample was taken per WAQTC TM 2?	❒	❒
4. Molds and base plate dampened and base plate is flat, level and fully supported?	❒	❒
5. Mold filled completely in one lift (slightly overfilled)?	❒	❒
6. Mold struck off level with top opening?	❒	❒
7. Excess material removed from base plate and mold raised 9 ± 3 inches, in 3 ± 1 seconds?	❒	❒
8. After flow stabilized, measured largest diameter (including halo if necessary)?	❒	❒
9. Second measurement taken approximately perpendicular to first measurement?	❒	❒
10.. First and second measurements agree within 2″?	❒	❒
11. Slump flow was reported as an average of the two measurements?	❒	❒
12. Slump flow reported to the nearest ¼″?	❒	❒

First attempt: Pass ❒ Fail ❒ Second attempt: Pass ❒ Fail ❒

Signature of Examiner ______________________________

Comments:

WSDOT FOP for ASTM D 4791[1]

Standard Test Method for Flat Particles, Elongated Particles, or Flat and Elongated Particles in Coarse Aggregate

1. Scope

1.1 This test method covers the determination of the percentages of flat particles, elongated particles, or flat and elongated particles in coarse aggregates.

1.2 The values stated in inch-pound units are to be regarded as the standard except in regard to sieve size and the size of aggregate, which are given in SI units in accordance with Specification E 11. The SI units in parentheses are for information purposes only.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

Note: WSDOT will be determining flat and elongated particles in accordance with section 8.4.

2. Referenced Documents

2.1 *WSDOT Standards:*

T 2 WSDOT FOP for AASHTO for the Sampling of Aggregates

T 248 WSDOT FOP for AASHTO for Reducing Field Samples of Aggregates to Testing Size

T 27/11 WAQTC FOP for AASHTO for the Sieve Analysis of Fine & Coarse Aggregates & Materials Finer Than 75 mm (No. 200) in Mineral Aggregates by Washing

3. Terminology

3.1 *Definitions:*

3.1.1 *flat or elongated particles of aggregate*—those particles of aggregate having a ratio of width to thickness or length to width greater than a specified value (see Terminology C 125).

3.1.2 *flat and elongated particles of aggregate*—those particles having a ratio of length to thickness greater than a specified value.

3.1.3 *length*—maximum dimension of the particle.

3.1.4 *width*—maximum dimension in the plane perpendicular to the length

3.1.5 *thickness*—maximum dimension perpendicular to the length and width.

[1] This Test Method is Based on ASTM D 4791-05 and has been modified per WSDOT standards. To view the redline modifications, contact WSDOT Quality Systems Manager at (360) 709-5412.

4. Summary of Test Method

 4.1 Individual particles of aggregate of specific sieve sizes are measured to determine the ratios of width to thickness, length to width, or length to thickness.

5. Significance and Use

 5.1 Flat or elongated particles of aggregates, for some construction uses, may interfere with consolidation and result in harsh, difficult to place materials.

 5.2 This test method provides a means for checking compliance with specifications that limit such particles or to determine the relative shape characteristics of coarse aggregates.

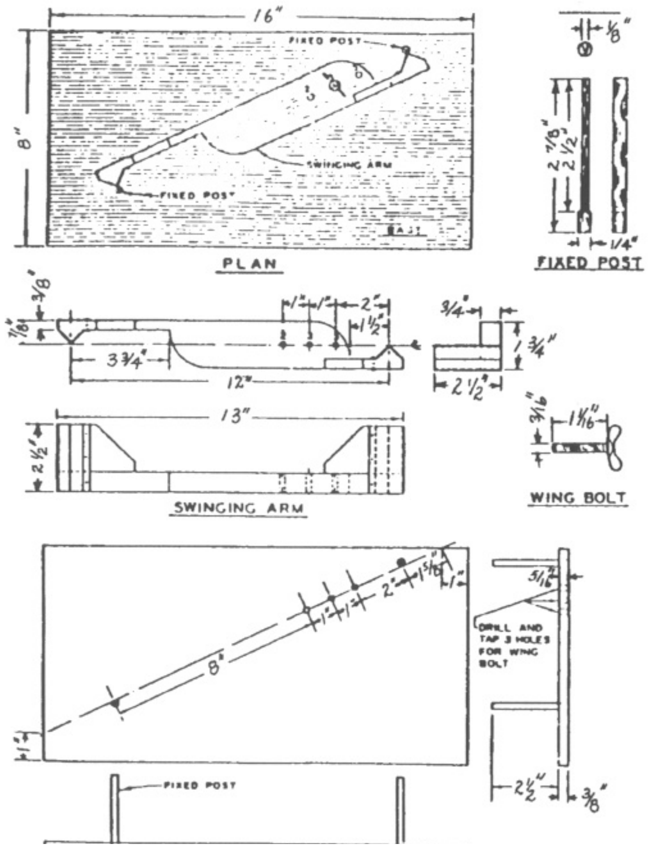
6. Apparatus

 6.1 The apparatus used shall be equipment suitable for testing aggregate particles for compliance with the definitions in 3.1, at the dimensional ratios desired.

  6.1.1 *Proportional Caliper Device*—The proportional caliper devices illustrated in Fig.1, Fig. 2, and Fig. 3 are examples of devices suitable for this test method. The device illustrated in Fig. 1 and Fig. 2 consists of a base plate with two fixed posts and a swinging arm mounted between them so that the openings between the arms and the posts maintain a constant ratio. The axis position can be adjusted to provide the desired ratio of opening dimensions. Fig. 1 illustrates a device on which ratios of 1:2, 1:3, 1;4, and 1:5 may be set. The device illustrated in Fig. 3 contains several fixed posts and has the capability of measuring various ratios simultaneously.

   6.1.1.1 *Verification of Ratio*—The ratio settings on the proportional caliper device shall be verified by the use of a machined block, micrometer, or other appropriate device.

  6.1.2 *Balance*—The balance or scales used shall be accurate to 0.5 % of the mass of the sample.



Proportional Caliper
Figure 1

7. Sampling

   7.1 Sample the coarse aggregate in accordance with in FOP for AASHTO T2. The mass of the field sample shall be the mass shown in FOP for AASHTO T2.

   7.2 Thoroughly mix the sample and reduce it to an amount suitable for testing using the applicable procedures described in FOP for AASHTO T 248. The sample for test shall be approximately the mass desired when dry and shall be the end result of the reduction. Reduction to an exact predetermined mass shall not be permitted. The mass of the test sample shall conform to the following:

Nominal Maximum Size* Square Openings, in. (mm)	Minimum Mass of Test Sample, lb (kg.)
⅜ (9.5)	2 (1)
½ (12.5)	4 (2)
¾ (19)	11 (5)
1 (25.0)	22 (10)
1½ (37.5)	33 (15)
2 (50)	44 (20)
2½ (63)	77 (35)
3 (75)	130 (60)
3½ (90)	220 (100)
4(100)	330 (150)
4½ (112)	440 (200)
5 (125)	660 (300)
6 (150)	1100 (500)

* For aggregate, the nominal maximum size, (NMS) is the largest standard sieve opening listed in the applicable specification, upon which any material is permitted to be retained. For concrete aggregate, NMS is the smallest standard sieve opening through which the entire amount of aggregate is permitted to pass.

Note: For an aggregate specification having a generally unrestrictive gradation (i. e. wide range of permissible upper sizes), where the source consistently fully passes a screen substantially smaller than the maximum specified size, the nominal maximum size, for the purpose of defining sampling and test specimen size requirements may be adjusted to the screen, found by experience to retain no more than 5% of the materials.

8. Procedure

8.1 If determination by mass is required, oven dry the sample in accordance with FOP for AASHTO T 255. If determination is by particle count, drying is not necessary.

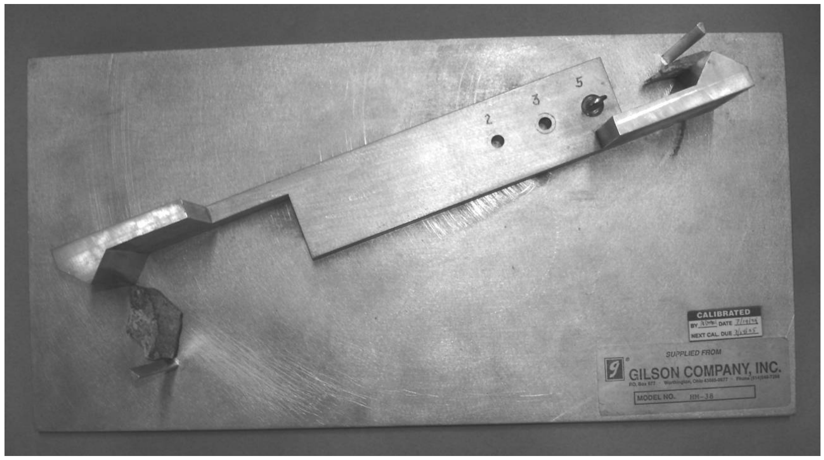
8.2 Sieve the sample to be tested in accordance with FOP for AASHTO T 27/11. If the material retained on each required size (⅜ and larger) is more than 5% of the sample, reduce the material in accordance with FOP for AASHTO T 248 until approximately 100 particles are obtained for each required size.

8.3 *Flat and Elongated Particle Test*—Test each of the particles in each size fraction and place in one of two groups: (1) flat and elongated or (2) not flat and elongated.

8.3.1 Use the proportional caliper device, set at the desired ratio.

8.3.2 *Measurement:*

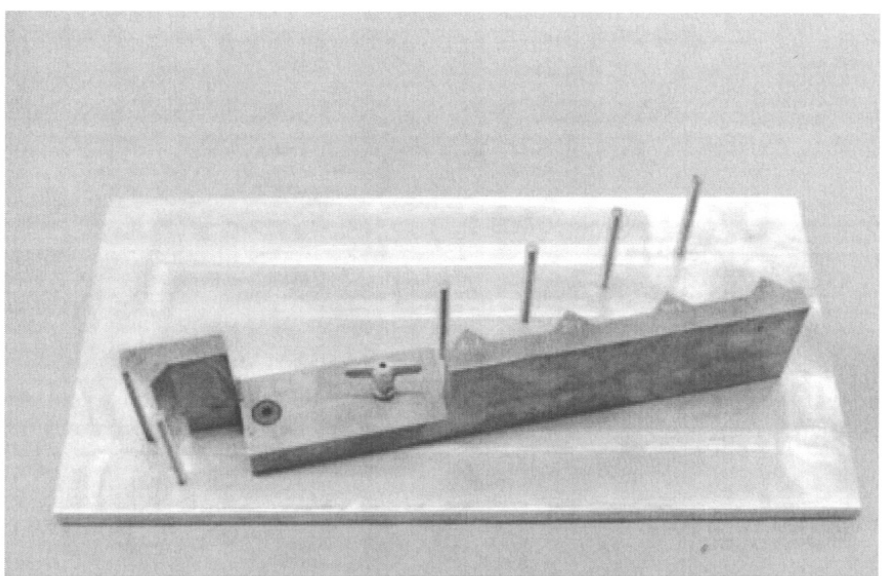
8.3.2.1 On proportional caliper devices similar to the devices shown in Fig. 1 and Fig. 2, set the larger opening equal to the length of the particle. The particle is flat and elongated if the particle, (biggest to smallest) when oriented to measure its thickness (biggest), can pass completely through the smaller opening of the caliper when it is rotated in any direction.



Use of Proportional Caliper
Figure 2

in.	mm	in.	mm	in.	mm
⅛	3.2	⅞	21.2	2½	64.0
3/16	4.8	1	25.4	2⅞	72.0
¼	6.3	1 1/16	27.0	3¾	96.0
5/16	7.9	1½	38.0	8	207.0
⅜	9.5	1⅝	41.0	16	414.0

Metric Equivalents



Proportional Caliper
Figure 3

8.4.2.2 On calipers similar to the one described in Fig. 3, set the minimum dimension of the proportional caliper device such that the particle, when oriented to measure its thickness, passes snugly between the post and swing arm. The particle is flat and elongated if the particle, when oriented to measure its length, fails to pass the desired large opening of the proportional caliper device.

8.4.3 After the particles have been classified into the groups described in 8.4, determine the proportion of the sample in each group by count or mass, as required.

Note: WSDOT performs this test by weight.

9. Calculation

9.1 Calculate the percentage of flat and elongated particles to the nearest 1% for each sieve size than ⅜ in. and larger (9.5 mm), as required.

10. Report

10.1 Include the following information in the report:

10.1.1 Identification of the coarse aggregate tested, and

10.1.2 Grading of the aggregate sample, showing percentage retained on each sieve.

10.1.3 For flat and elongated particle tests:

10.1.3.1 Percentages, calculated by number or by mass, or both, for flat and elongated particles for each sieve size tested,

10.1.3.2 The dimensional ratio used in the tests, and

10.1.4 When required, weighted average percentages based on the actual or assumed proportions of the various sieve sizes tested. Report the grading used for the weighted average if different from that in 10.1.2.

10.2 Report results using WSDOT form 350-161, or other report approved by the State Materials Engineer.

11. Precision and Bias

See ASTM D 4791 for precision and bias statements.

12. Keywords

12.1 aggregates; coarse aggregates; particle shape

Performance Exam Checklist

FLAT AND ELONGATED PARTICLES IN COARSE AGGREGATE
FOP FOR ASTM D 4791

Participant Name ____________________________ Exam Date ______________

Procedure Element	Yes	No
1. The tester has a copy of the current procedure on hand?	❒	❒
2. All equipment is functioning according to the test procedure, and if required, has the current calibration/verification tags present?	❒	❒
3. Field sample obtained per AASHTO T-2?	❒	❒
4. Sample thoroughly mixed prior to reducing to testing size?	❒	❒
5. Sample reduced to testing size per AASHTO T-248?	❒	❒
6. Mass of the test sample conforms to the table in Section 7.2, ASTM D-4791?	❒	❒
PROCEDURE		
1. If determination by mass, sample oven dried to a constant weight prior to mass determination?	❒	❒
2. Sample sieved per AASHTO T 27/T 11?	❒	❒
3. Proportional caliper device positioned at proper ratio?	❒	❒
4. Each size fraction 3/8 inch and larger retaining more than 5% of the original sample reduced per AASHTO T-248 until approximately 100 particles are obtained for each size fraction required?	❒	❒
5. Each particle of each size fraction tested for FLAT and ELONGATED using the proportional caliper device put in the appropriate group classification? (Flat & Elongated or Not flat & Elongated)	❒	❒
6. Proportion of the sample of each sieve size determined by Mass?	❒	❒
7. Percent of Flat and Elongated particles figured to the nearest 1% for each sieve size?	❒	❒
8. Record number of particles in each sieve size tested?	❒	❒
9. Record percentages calculated by Mass?	❒	❒
10. All calculations performed correctly?	❒	❒

First attempt: Pass ❒ Fail ❒ Second attempt: Pass ❒ Fail ❒

Signature of Examiner __________________________________

Comments:

WSDOT FOP for ASTM D 7012

Standard Test Method for Unconfined Compressive Strength of Intact Rock Core Specimens

ASTM D 7012 has been adopted by WSDOT with the following changes and/or additions:

The standard preparation of specimens for the above test will be as described below.

4. Test Specimens

   4.1 Specimen arrives cut to length, ready for testing

   4.2 Specimens are measured for length to the nearest 0.01 in (0.25 mm) at the centers of the faces.

   4.3 Specimens are measured for diameter to the nearest 0.01 in (0.25 mm) by averaging two diameters measured at right angles to each other at about mid height of the specimen.

   4.4 The specimen ends are checked that they are at right angles to the longitudinal axis. The ends are recut if greater than 5 degrees different from a right angle.

   4.5 The specimen shall have a length to diameter ratio of 2.0 to 2.5 and the diameter shall be greater than 1⅞ inch (48 mm).

Performance Exam Checklist

Nondestructive Measurement of Thickness of Nonmagnetic Coatings on a Ferrous Base
FOP For ASTM D 7091

Technician Name ______________________ Exam Date ______________

Procedure Element	Yes	No
1. The tester has a copy of the current procedure on hand?	❐	❐
2. All equipment is functioning according to the test procedure, and if required, has the current calibration/verification tags present?	❐	❐
3. Instrument calibrated in accordance with the manufacturer's instructions before use employing a suitable thickness standard?	❐	❐
4. Several readings taken and recorded taking into account edge and curvature effects?	❐	❐
5. The average thickness converted to oz. ft^2 (g/m^2) using appropriate conversion factor?	❐	❐

First attempt: Pass ❐ Fail ❐ Second attempt: Pass ❐ Fail ❐

Signature of Examiner ______________________

Comments:

A

B

C

D

S